1963 - Sept

A TEMPERATURE ATLAS OF THE GULF OF PANAMA 1955 – 1959

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by Paul N Sund

Woods Hole Oceanographic Institution
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A TEMPERATURE ATLAS OF THE GULF OF PANAMA

1955-1959

by

Paul N. Sund

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Woods Hole Oceanographic Institution
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SEP 1963

A TEMPERATURE ATLAS OF THE GULF OF PANAMA

1955-1959*

by

Paul N. Sund

ACKNOWLEDGEMENTS

The temperature charts were initially contoured by Y. M. M. Bishop and C. T. Psaropulos, and drawn in their present form by E. B. Bennett, of the Inter-American Tropical Tuna Commission. The efforts of these persons are gratefully acknowledged. Thanks are also expressed to the staff and technicians of the Commission's Panama Laboratory, who collected the field data.

INTRODUCTION

The interests of the Inter-American Tropical Tuna Commission in the hydrography and biology of the Gulf of Panama have been adequately stated in the Commission's <u>Bulletin</u> series (Forsbergh, 1963; Howard, 1954; Howard and Landa, 1958; Peterson, 1961; Schaefer, 1953; Schaefer and Bishop, 1958; Schaefer, Bishop and Howard, 1958). The present report deals with data collected on 10 surveys made by Tuna Commission personnel for the purpose of describing seasonal upwelling by means of a study of the temperature structure of the Gulf of Panama, and a comparison of the thermal pattern during the dry, upwelling season (January to April) with that of the rainy season (May to December). Considerations of upwelling in the Gulf have been shown to be of interest and of probable biological consequence by Schaefer (1957) and by Simpson (1959).

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*This study was in part supported by Atomic Energy Commission Contract AT (11-1)-34 Project 99 with the Institute of Marine Resources of the University of California.

Fleming (1935) described two areas of upwelling, one in Panama Bay and one to the southeast of the Archipelago de las Perlas. He estimated that the upwelled water replaces 40 m of surface water during the season, but later (1940) he revised this estimate to 75 m. Schaefer (1957) and Schaefer, Bishop and Howard (1958) estimated that the water upwelled at least 50 and 40 m, respectively. Forsbergh (1963) found an average of 78 m of water replaced by upwelling during the January to April dry season in Panama Bay and at the head of the Gulf.

The rate of upwelling can be calculated by the time change with depth of the isotherms. However, the time intervals between the surveys considered here are not such that this is possible. The shorter time interval between observations at the Commission's permanent station makes those data more properly adaptable to this calculation, and for such, one is referred to Forsbergh (1963).

It would also be of interest to compare other hydrographic and biological features with upwelling. This has been done by Forsbergh (1963). It is therefore suggested that simultaneous reference to that paper will increase the value of this report. One also is referred to the paper by Wooster (1959) for a general discussion of the oceanography of the Gulf of Panama and the Panama Bight.

METHODS

The data used in this report were collected over the period 1955 to 1959. Temperature was measured by means of a bathythermograph (BT). Readings were corrected at the surface with a bucket thermometer and at 20 m with a reversing thermometer. The bathythermograms were processed by the BT Section of the University of California, San Diego, Scripps Institution of Oceanography. [Copies of the bathythermograms are available at the National Oceanographic Data Cen-

ter, Washington, D.C.]. The temperature distributions at 0, 10, 25, 50 and 75 m at the time of the surveys are illustrated in Figures 2-47. The locations of stations occupied during each of the 10 surveys are indicated on the surface temperature charts by dots. Figure 1 illustrates the bathymetry of the region, and Figure 48 shows the deviations of mean monthly temperatures at Naos Island, Canal Zone, from the long-term monthly mean. Data for the last figure were taken from Coast and Geodetic Survey Publication 31-3 (1962).

COMMENTS ON, AND INTERPRETATION OF, THE FIGURES

Bathymetry. Figure 1

The Gulf of Panama is a shoal area less than 200 m deep. The Las Perlas Islands lie within the Gulf, east of its center. To the west of these islands the bottom contours penetrate farthest northward, so that the thalweg lies in a shallow trough directed toward the head of the Bay of Panama.

Survey #1, 20-22 March 1955. Figures 2-6

The waters ranged in temperature from 21° to 26°C at the surface, and below 25 m temperatures were between 14° and 19°C. The strongest northerly winds for the year were recorded during this month and sea level was lowest. The surface temperature was the lowest over a greater portion of the Gulf of Panama during this period than during any other observational period considered here. This cold pattern coincides with the observations of Bennett (1963) who noted that 1955 was an exceptionally cold period in the Eastern Tropical Pacific. The greater cold anomaly is also noticeable in Figure 48.

The isotherm pattern is consistent with strong upwelling at the head of the Gulf (Bay of Panama) and perhaps off San Miguel Bay. The latter location is noted tentatively because of the lack of other upwelling indices and the possibility that the low temperatures recorded off that bay may simply be the result of an influx of cooler river water into the Gulf. At depths of 50 and 75 m, maximum penetration of cool water is on the west side of the Gulf, along

the trough in the bottom.

Survey #2, 27-29 July 1955. Figures 7-10.

The waters of the Gulf warmed considerably since March, and were greater than 27°C at the surface and warmer than 18° at 50 m. It is evident that the coldest water reached farthest into the Gulf along the trough in the western side. The isotherm pattern can be interpreted as indicative of a general counterclockwise circulation near the surface, as was reported by Wooster (1959).

Survey #3, 28-30 November 1955. Figures 11-14.

Warm water still persisted throughout the Gulf of Panama at the time of this survey. Warming progressed so that the temperatures at 50 m were in the range of 19°-24°C, compared to 15°-16° in March.

Survey #4, 5-6 April 1956. Figures 15-17.

The area west of the Archipelago de las Perlas was cooler than that to the east of these islands due to upwelling of cooler waters at the Bay of Panama. The period in which this cruise was made followed the time of strongest northerly winds of the season. A second location of upwelling is indicated near San Miguel Bay.

The "double" upwelling period reported by Schaefer, Bishop and Howard (1958) and by Forsbergh (1963) is not reflected in the present data, because of the short time over which these observations were made.

Survey #5, 4-5 September 1956. Figures 18-22.

Temperatures in the upper 10 m over most of the Gulf were at least 28°C at the time of this survey. In the 25-50 m depth range, temperatures had warmed to 18-27°C, and were 15-16°C at 75 m. The cold water entering along the deepest portion of the Gulf is indicated by the isotherm patterns at 50 and 75 m. One also notes that the warm water reached greater depths in the eastern half of the Gulf.

Survey #6, 17-20 March 1957. Figures 23-27.

Temperatures at this time ranged from 21°-26°C at the surface, and were coolest offshore. The isotherms at 10 and 25 m show upwelling with the coolest water near the head of Panama Bay and near the Bay of San Miguel. Warm waters persisted offshore and to the south. The upwelling was supplied with cool water entering along the trough west of the Las Perlas Islands.

Survey #7, 10-12 July 1957. Figures 28-32.

The waters were warmer than 27°C over most of the Gulf to depths of about 25 m, and were about 19° or warmer to all depths recorded. This, then, is the warmest period encountered in these surveys.

Survey #8, 7-8 November 1957. Figures 33-37.

Warm temperatures still prevailed over most of the Gulf of Panama at this time, but the recorded values are 1°-3° cooler than at the time of the previous survey. A warm water tongue was present above 25 m, while warmest waters at 50 m appeared in an area centered southwest of the Las Perlas Islands. The isotherm pattern is consistent with the usual current pattern of counterclockwise flow through the Gulf, near the surface.

Survey #9, 18-21 March 1958. Figures 38-42.

The Gulf water was cool at the time of this survey but,according to data included in Forsbergh's paper,was not minimal for the season. The isotherms suggest a southward flow of upwelled water at the surface out of the Bay of Panama. This flow is evident to at least 25 m, with cool water present in the center of the Gulf and warm water on each side. The southward current seems more evident than at the times of the previous surveys, and may be a consequence of El Niño conditions prevailing at the time. At depths of 50 and 75 m, the isotherms indicate a transport into the Gulf in the western side toward its head.

Survey #10, 10-13 April 1959. Figures 43-47.

The usual upwelling pattern is evident at this time. There were flows of cool upwelled water out of the Bay of Panama and the Bay of San Miguel. The southward flow of surface waters is noted to include only those waters above 10 m. The isotherm patterns at 50 and 75 m indicate an inflow of cool water along the trough in the west side of the Gulf.

SUMMARY

Upwelling is evident from the temperature distributions during surveys made in March 1955, April 1956, March 1957 and 1958, and April 1959. The isotherm patterns indicate a southward flow of upwelled water at the surface out of the Bay of Panama and perhaps also out of San Miguel Bay in the eastern side of the Gulf. Cool water apparently enters the Gulf along and above a trough in the western side, about half-way between the western coast of Panama and the Archipelago de Las Perlas. This inflow is present during times of upwelling as well as during times when warm water is present throughout the area. In a few instances, the pattern of isotherms indicates a general counterclockwise circulation at and near the surface.

The figures indicate that water is upwelled from depths of at least 50 m, which is in general agreement with published estimates of 35-75 m.

The data also are consistent with published interpretations for the period surveyed regarding the general conditions in the Eastern Tropical Pacific. These, briefly, are that 1955 was colder than usual; 1956 was cool, but near the long-term means of temperature and other hydrographic conditions; 1957 and 1958 were unusually warm (the warmest surface waters were recorded in July 1957); and 1959 showed a return from the warm situation to one more near the long-term mean.

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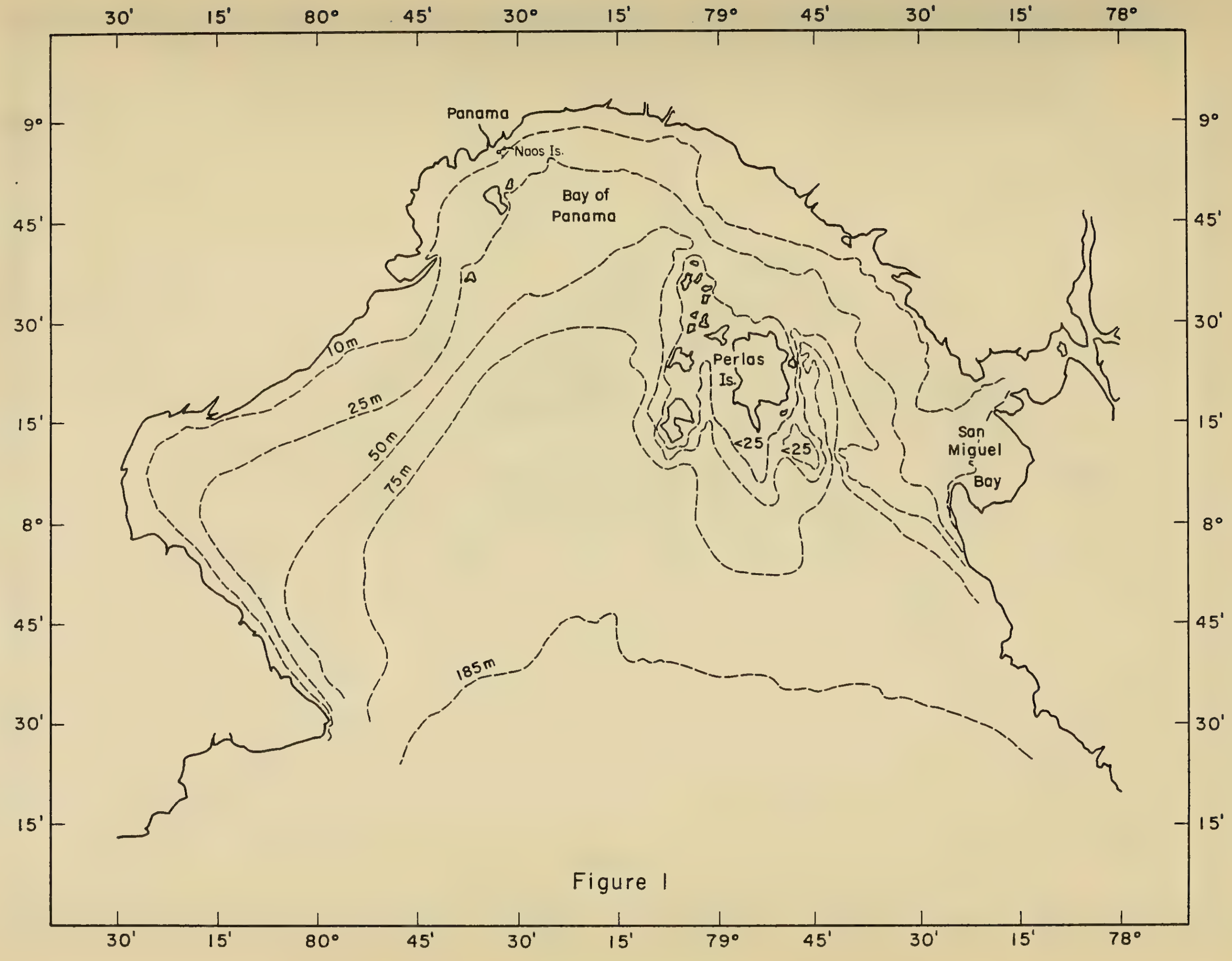
FIGURES

FIGURE 1.	Bathymetry of the Gulf of Panama. After H. O. 1019.
FIGURE 2.	Temperature distribution at the surface, 20-22 March 1955
FIGURE 3.	" " " 10 m, " " "
FIGURE 4.	" " " 25 m, " " "
FIGURE 5.	" " " 50 m, " " "
FIGURE 6.	" " " 75 m, " " "
FIGURE 7.	" " at the surface, 27-29 July 1955
FIGURE 8.	" " " 10 m, " " "
FIGURE 9.	" " " 25 m, " " "
FIGURE 10.	" " " 50 m, " " "
FIGURE 11.	" " at the surface, 28-30 November 1955
FIGURE 12.	" " " 10 m, " " "
FIGURE 13.	" " " 25 m, " " "
FIGURE 14.	" " " 50 m, " " "
FIGURE 15.	" " at the surface, 5-6 April 1956
FIGURE 16.	" " " 10 m, " " "
FIGURE 17.	" " " 25 m, " " "
FIGURE 18.	" " at the surface, 4-6 September 1956
FIGURE 19.	" " " 10 m, " " "
FIGURE 20.	" " " 25 m, " " "
FIGURE 21.	" " " 50 m, " " "
FIGURE 22.	" " " 75 m, " " "
FIGURE 23.	" " at the surface, 17-20 March 1957
FIGURE 24.	" " " 10 m, " " "
FIGURE 25.	" " " 25 m, " " "
FIGURE 26.	" " " 50 m, " " "
FIGURE 27.	" " " 75 m, " " "
FIGURE 28.	" " at the surface, 10-12 July 1957
FIGURE 29.	" " " 10 m, " " "
FIGURE 30.	" " " 25 m, " " "
FIGURE 31.	" " " 50 m, " " "
FIGURE 32.	" " " 75 m, " " "
FIGURE 33.	" " at the surface, 7-8 November 1957
FIGURE 34.	" " " 10 m, " " "
FIGURE 35.	" " " 25 m, " " "
FIGURE 36.	" " " 50 m, " " "
FIGURE 37.	" " " 75 m, " " "
FIGURE 38.	" " at the surface, 18-21 March 1958
FIGURE 39.	" " " 10 m, " " "
FIGURE 40.	" " " 25 m, " " "
FIGURE 41.	" " " 50 m, " " "
FIGURE 42.	" " " 75 m, " " "

FIGURE 43. Temperature distribution at the surface, 10-13 April 1959
FIGURE 44. " " " 10 m, " " "
FIGURE 45. " " " 25 m, " " "
FIGURE 46. " " " 50 m, " " "
FIGURE 47. " " " 75 m, " " "

FIGURE 48. Deviations from long-term monthly mean temperatures at Naos Island Canal Zone, 1955-1959.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80°
45'
30°
15'
79°
45'
30'
15'
78°
9°
45'
30'
15'
8°
45'
30'
15'
Panama
Naos Is.
Bay of
Panama
Perlas
Is.
San
Miguel
Bay
10m
25m
50m
75m
185m
<25
<25

Figure 1

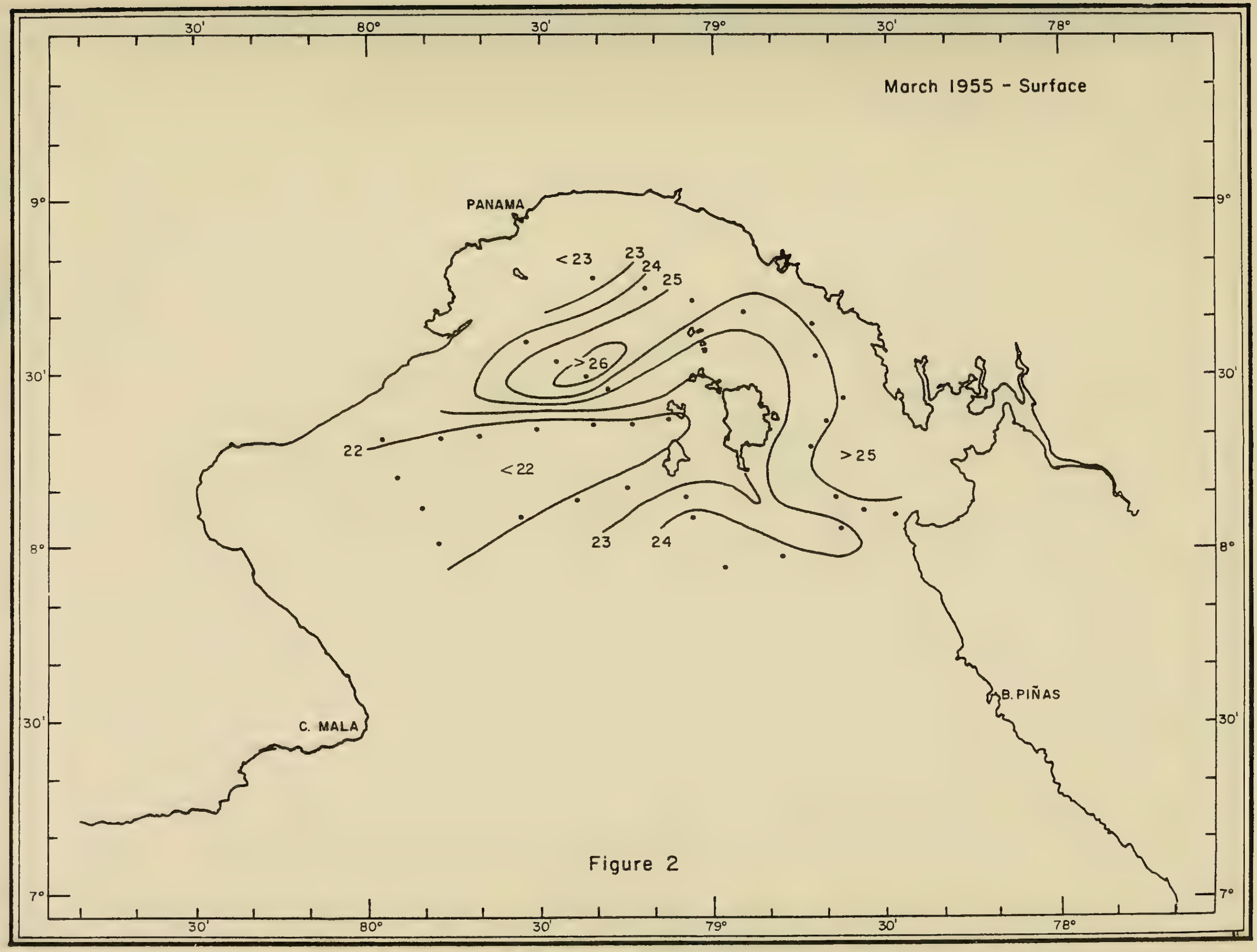

March 1955 - Surface
PANAMA
C. MALA
B. PIÑAS
<23
23
24
25
>26
22
<22
>25
23
24
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 2

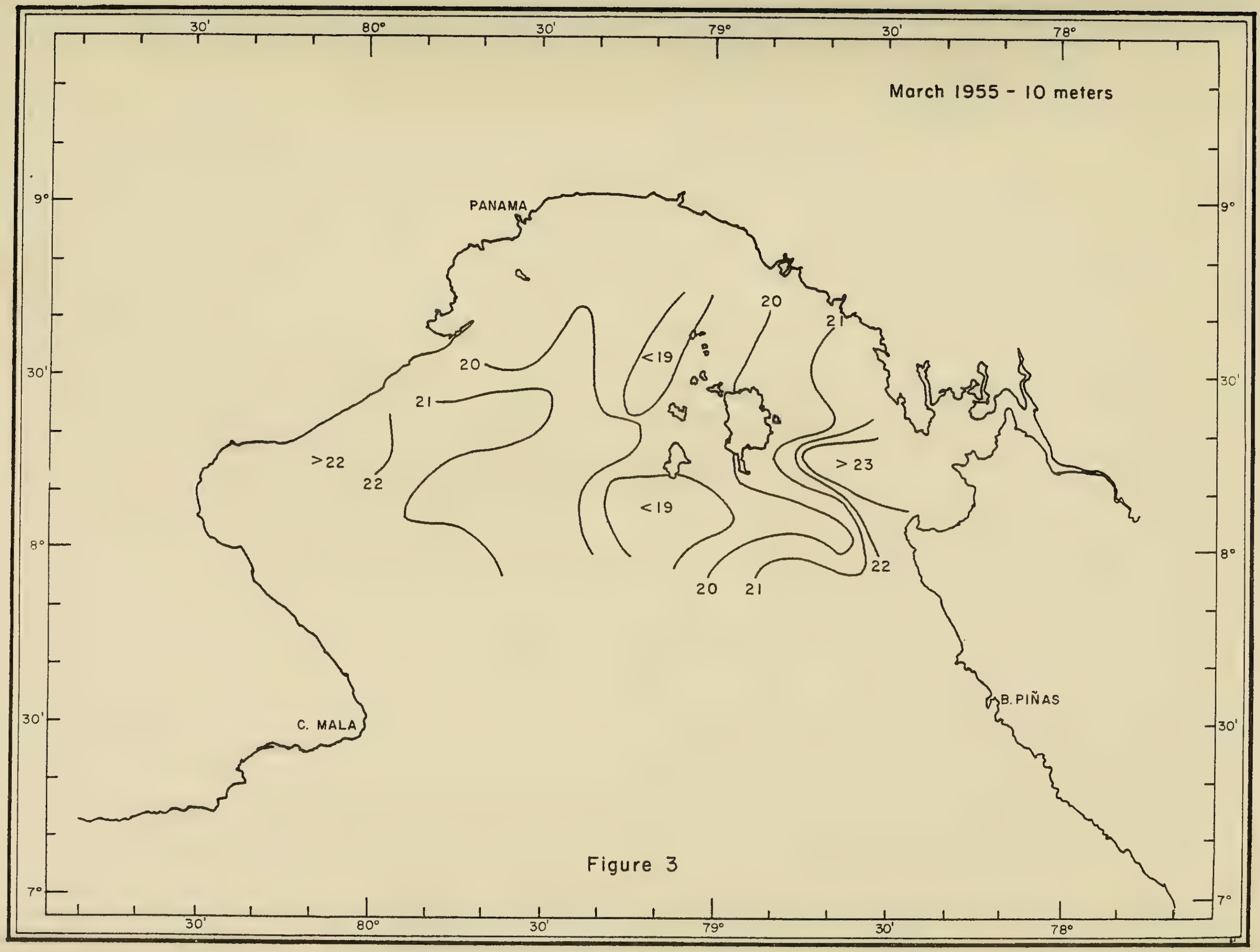
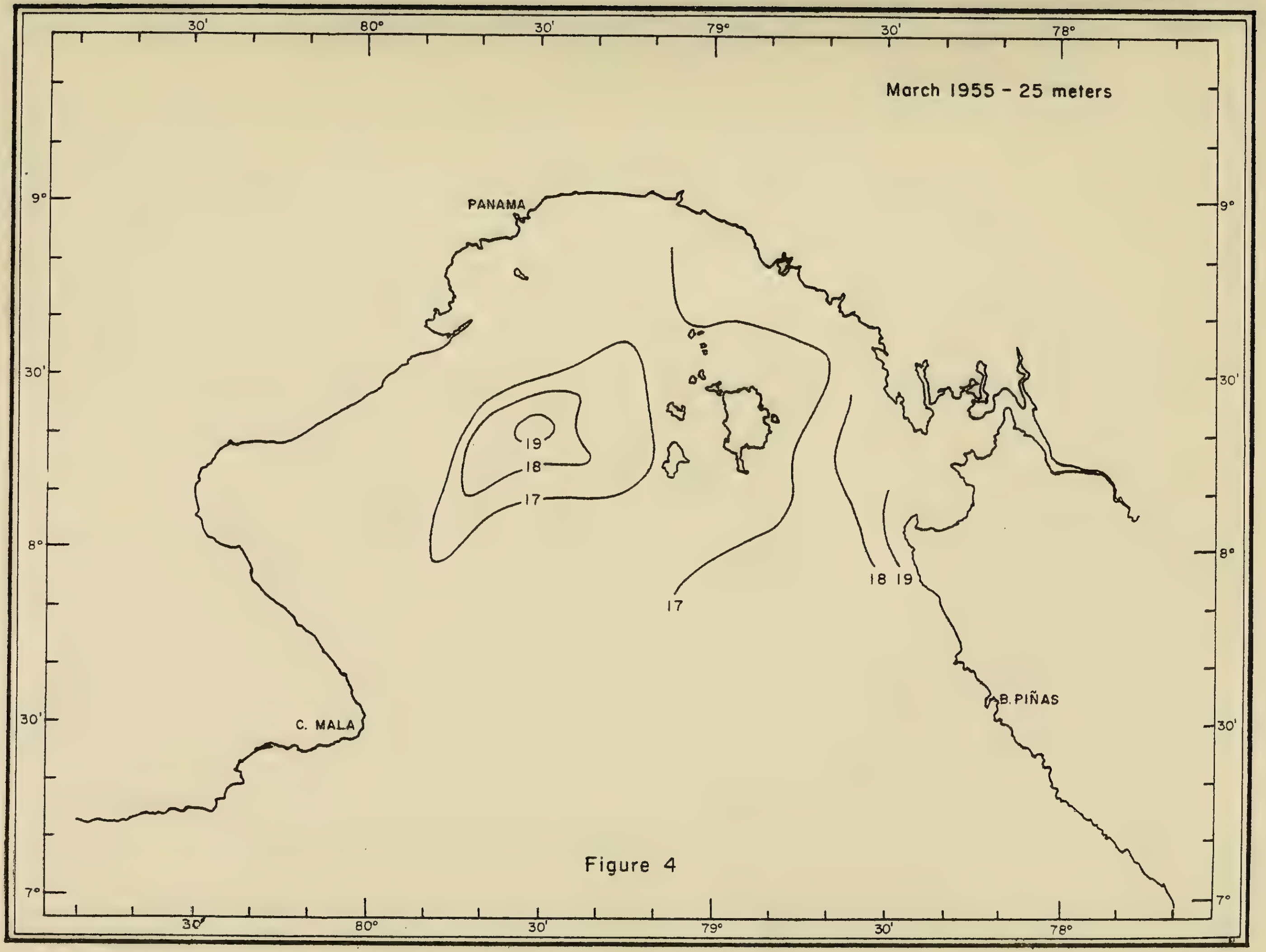

March 1955 - 10 meters
PANAMA
C. MALA
B. PIÑAS
20
21
22
>22
<19
<19
20
21
22
>23
80°
79°
78°
30'
9°
8°
7°

Figure 3



March 1955 - 25 meters
PANAMA
C. MALA
B. PIÑAS
19
18
17
17
18
19
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 4

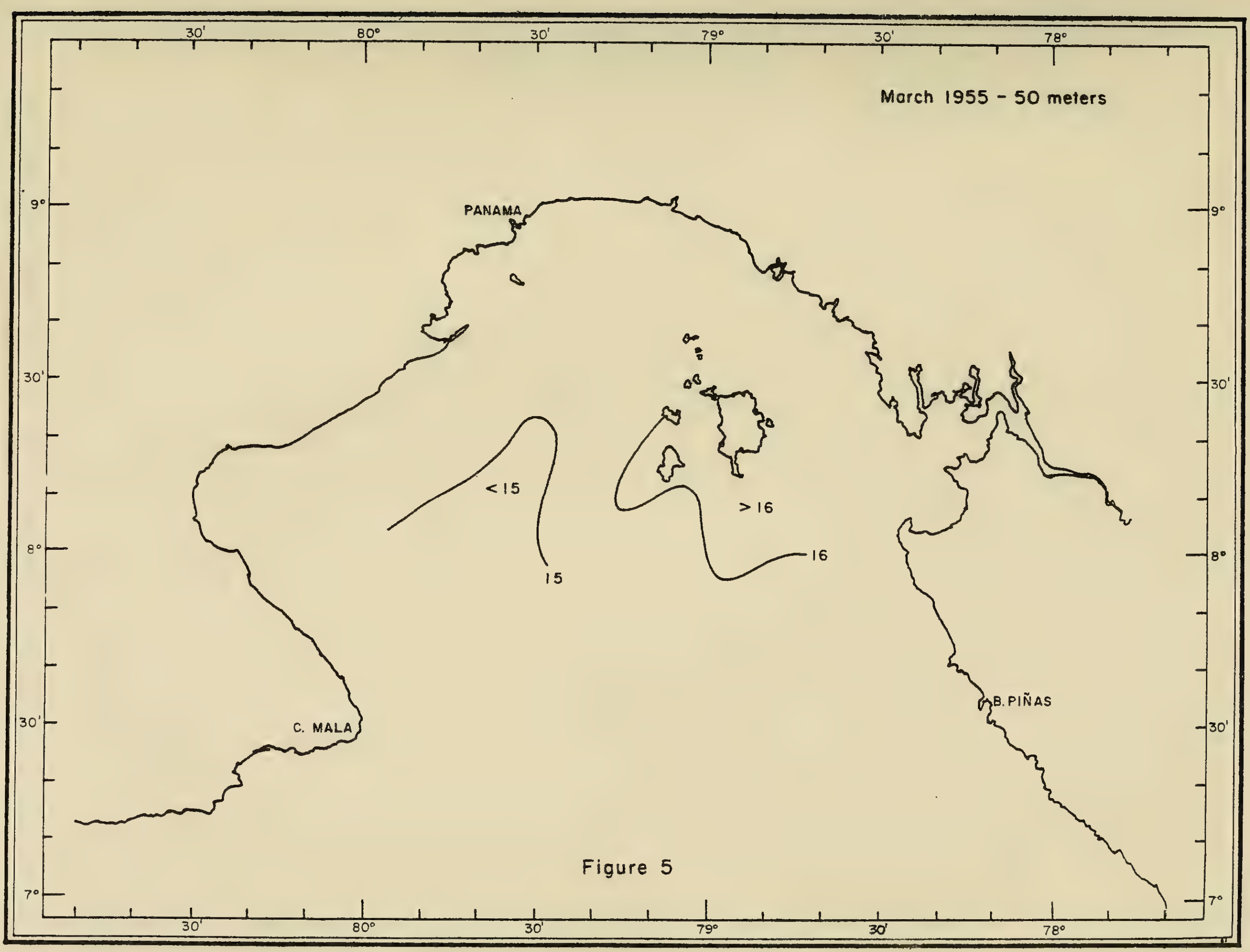

March 1955 - 50 meters
PANAMA
C. MALA
B. PIÑAS
<15
15
>16
16
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 5

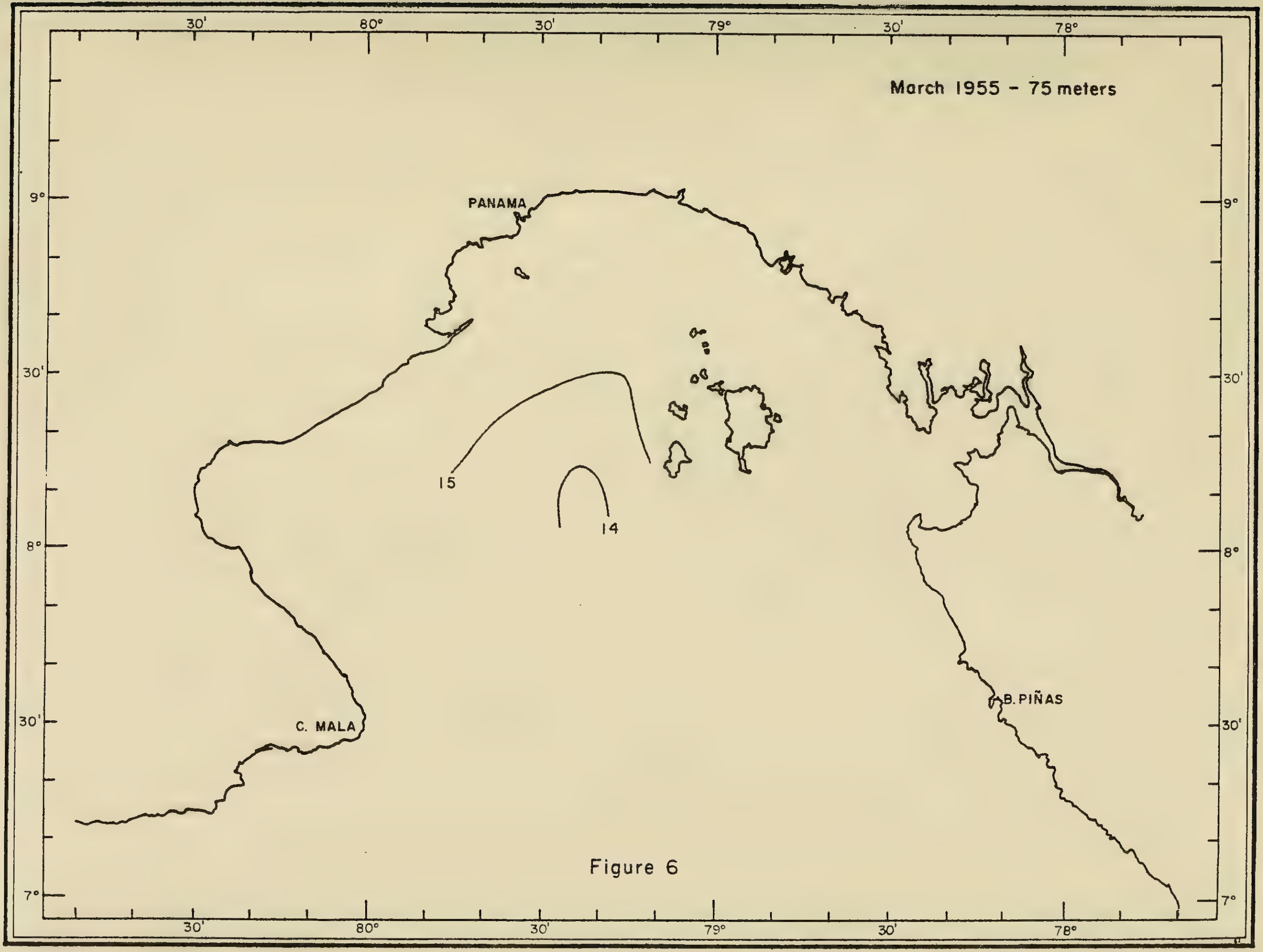

March 1955 - 75 meters
PANAMA
C. MALA
B. PIÑAS
15
14
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 6

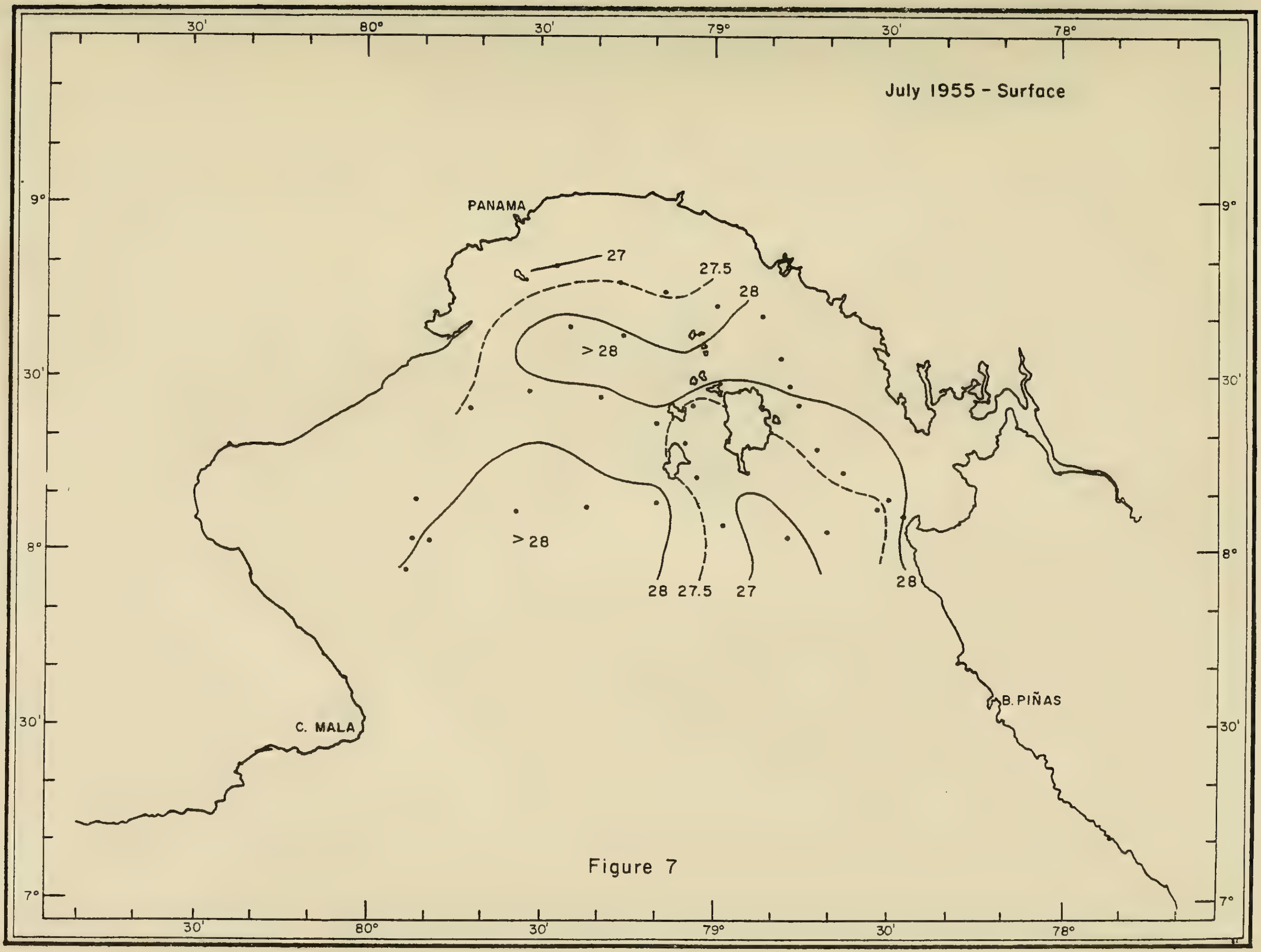
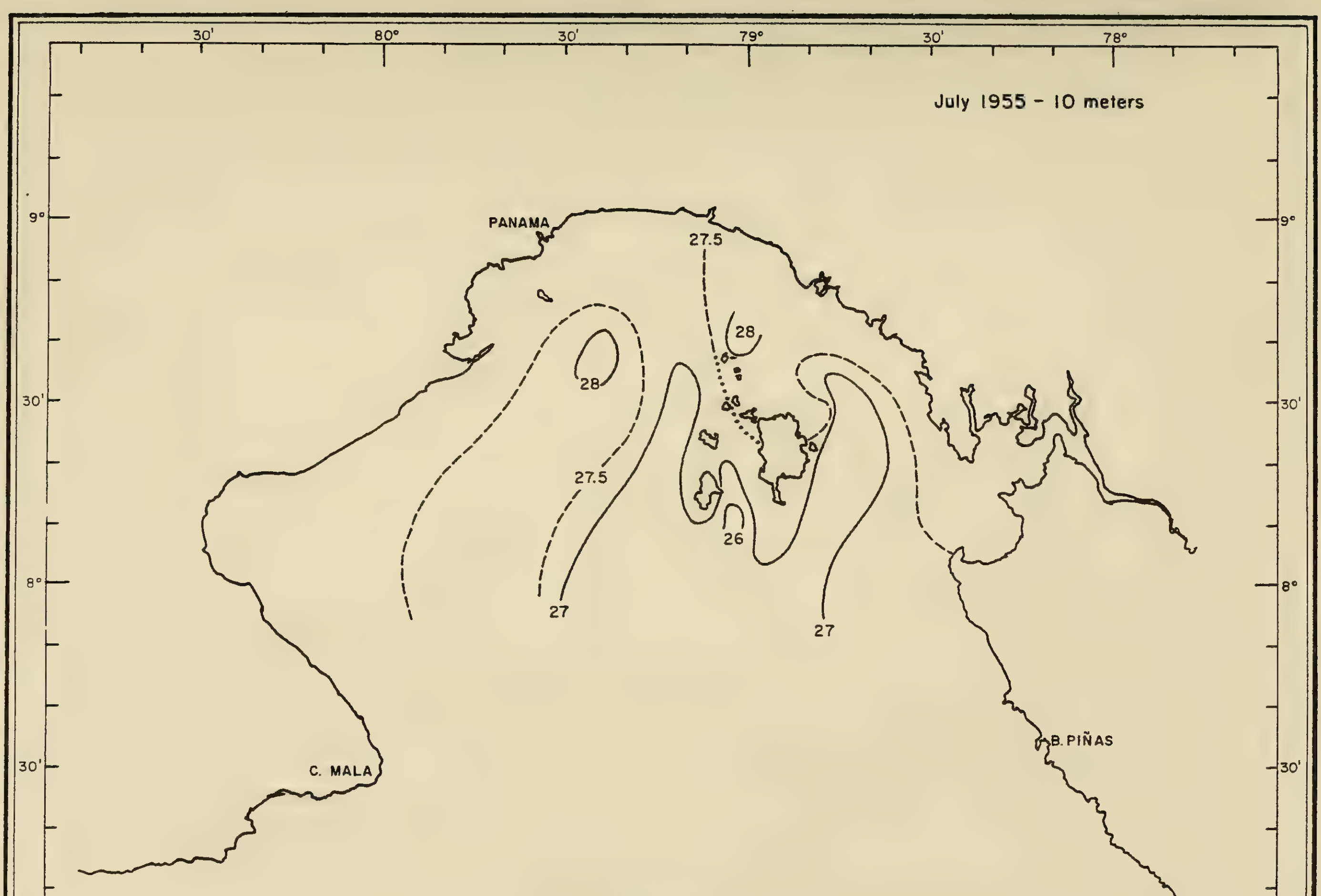

July 1955 - Surface
PANAMA
C. MALA
B. PIÑAS
27
27.5
28
> 28
> 28
28
27.5
27
28
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 7



July 1955 - 10 meters
PANAMA
C. MALA
B. PIÑAS
27.5
28
28
27.5
27
26
27
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 8

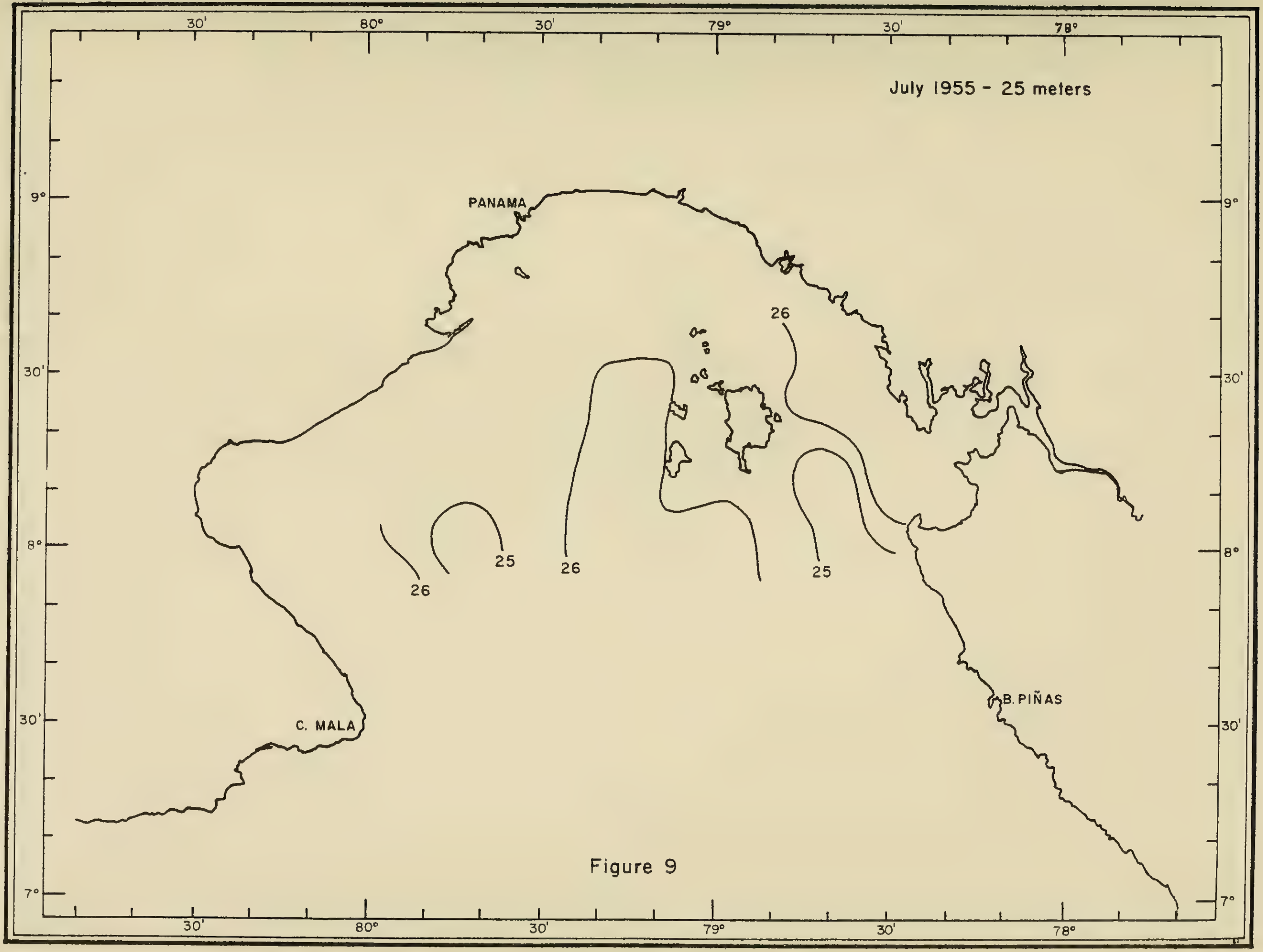

July 1955 - 25 meters
PANAMA
C. MALA
B. PIÑAS
26
25
26
25
26
26
25
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 9

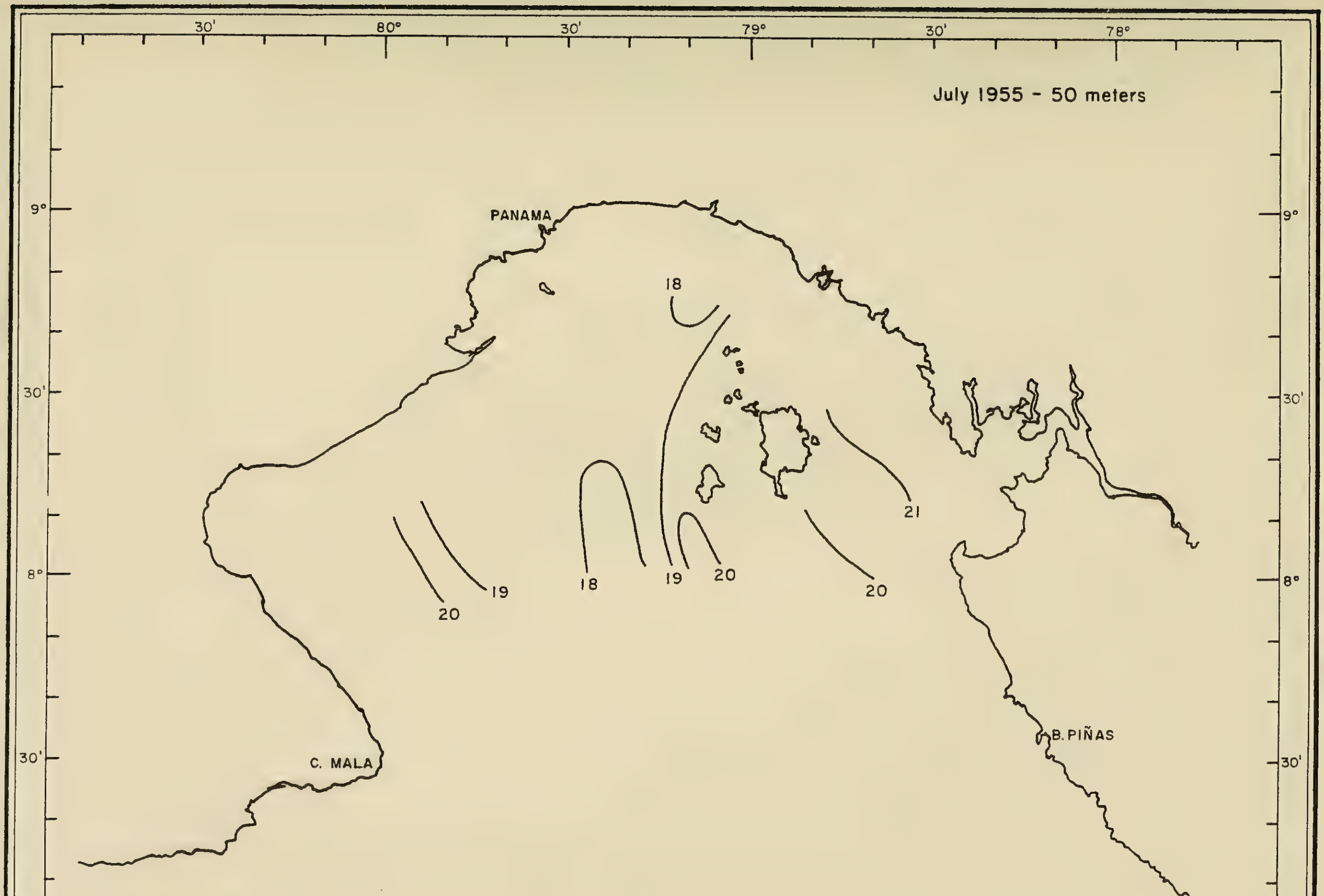

July 1955 - 50 meters
PANAMA
C. MALA
B. PIÑAS
18
19
20
21
30'
80°
79°
78°
9°
8°
7°

Figure 10

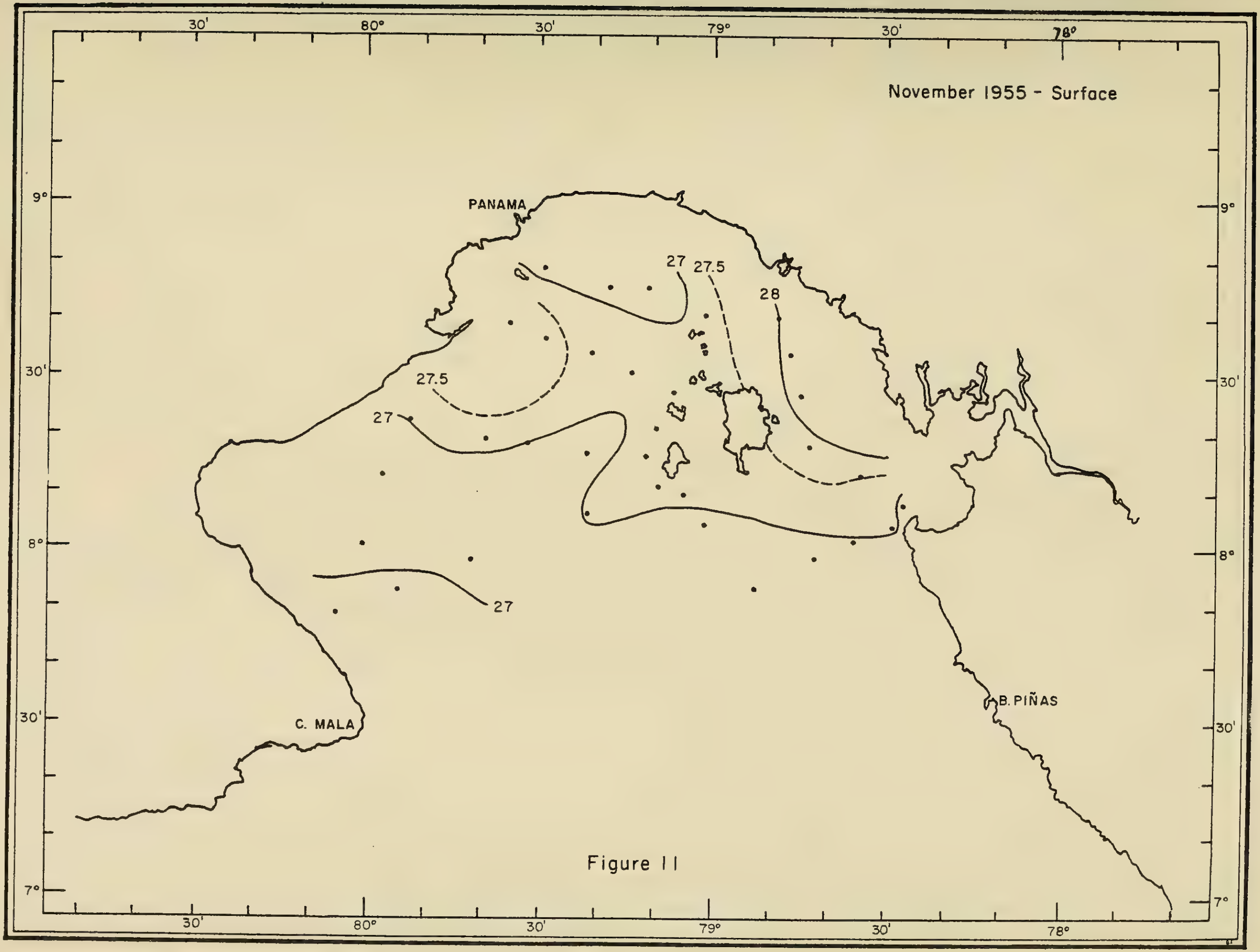
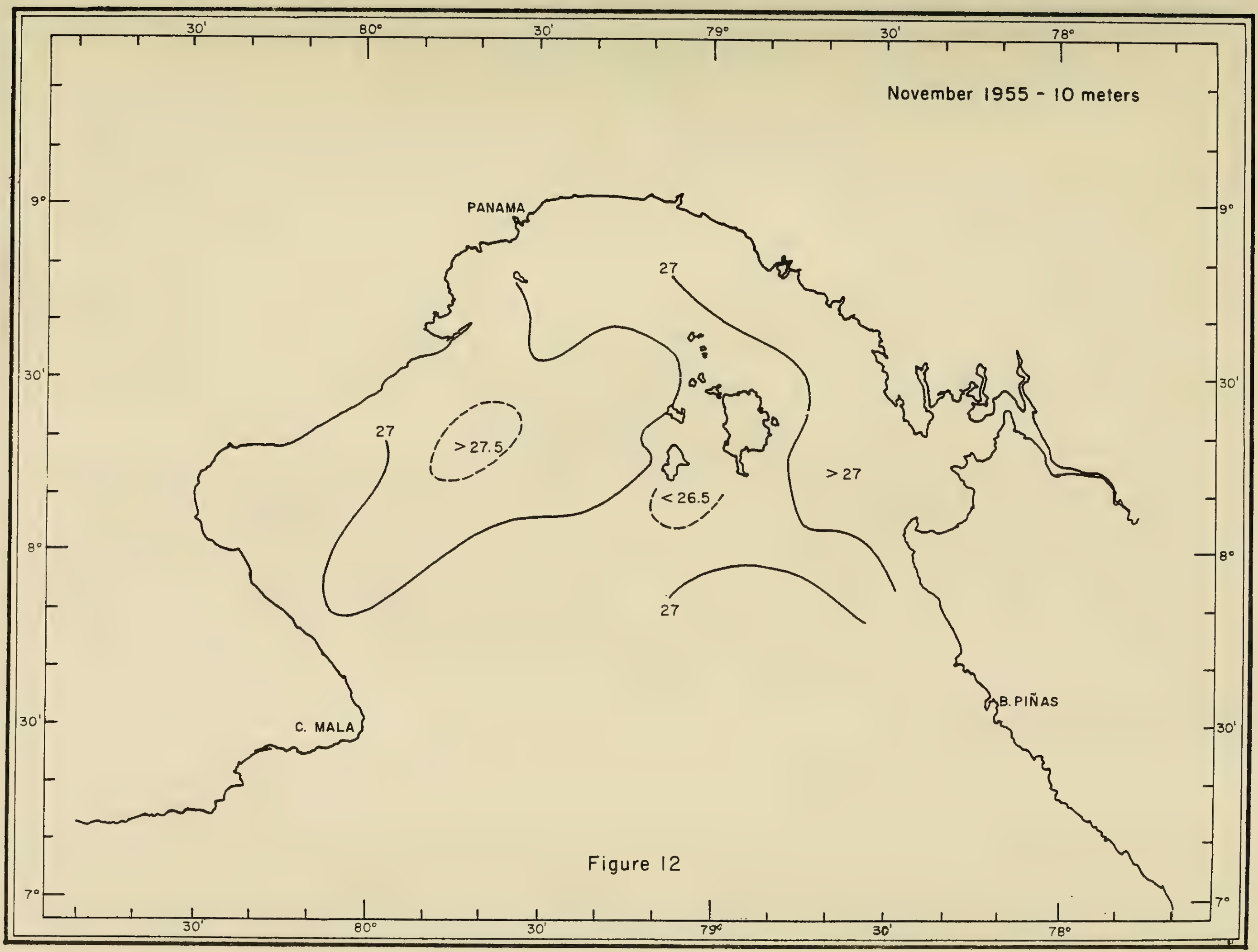

November 1955 - Surface
PANAMA
C. MALA
B. PIÑAS
27
27.5
28
27.5
27
27
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 11



November 1955 - 10 meters
PANAMA
C. MALA
B. PIÑAS
27
>27.5
27
<26.5
>27
27
9°
30'
8°
30'
7°
30'
80°
30'
79°
30'
78°

Figure 12

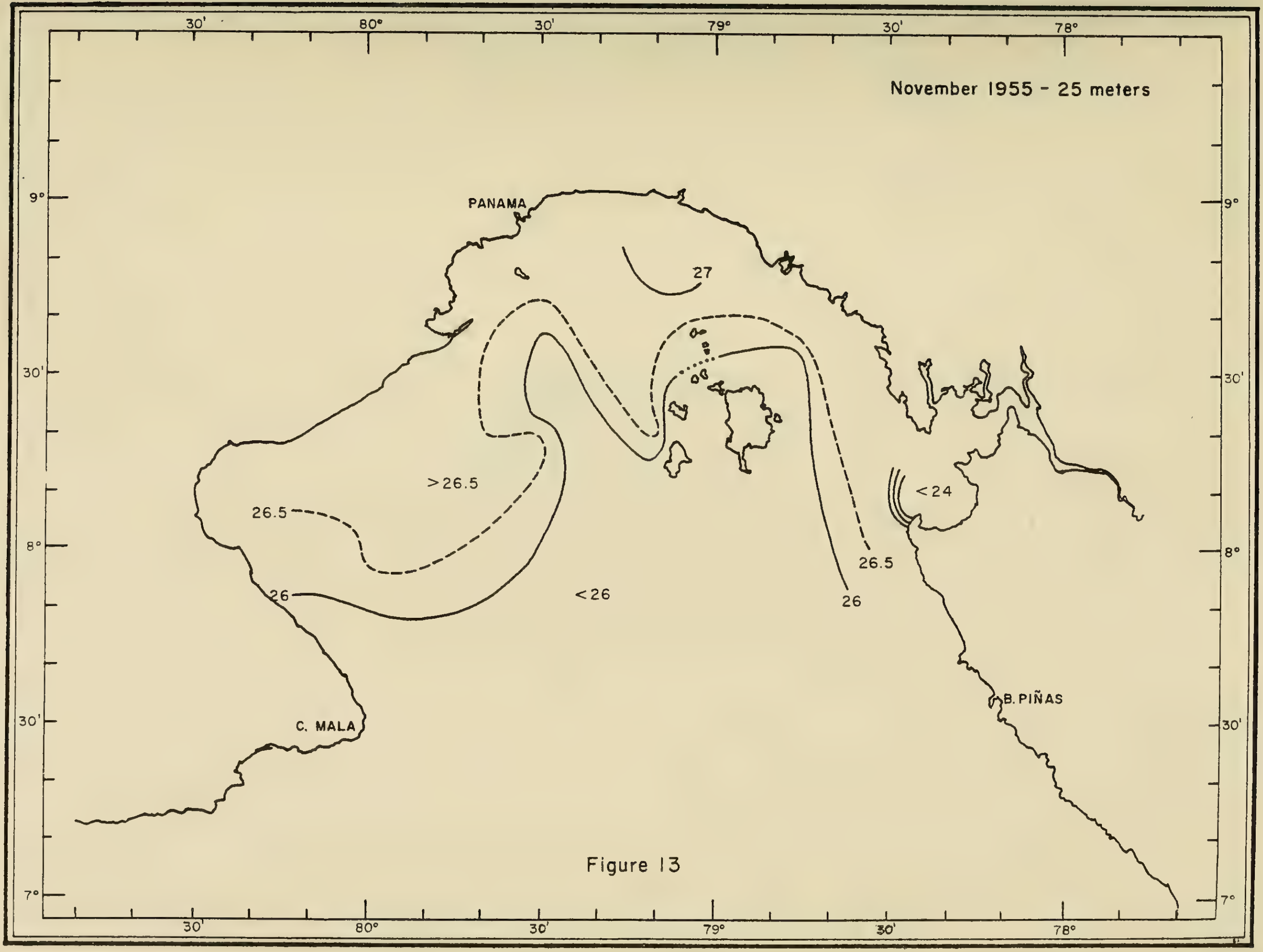

November 1955 - 25 meters
PANAMA
C. MALA
B. PIÑAS
27
26.5
>26.5
26
<26
<24
30'
80°
79°
78°
9°
8°
7°

Figure 13

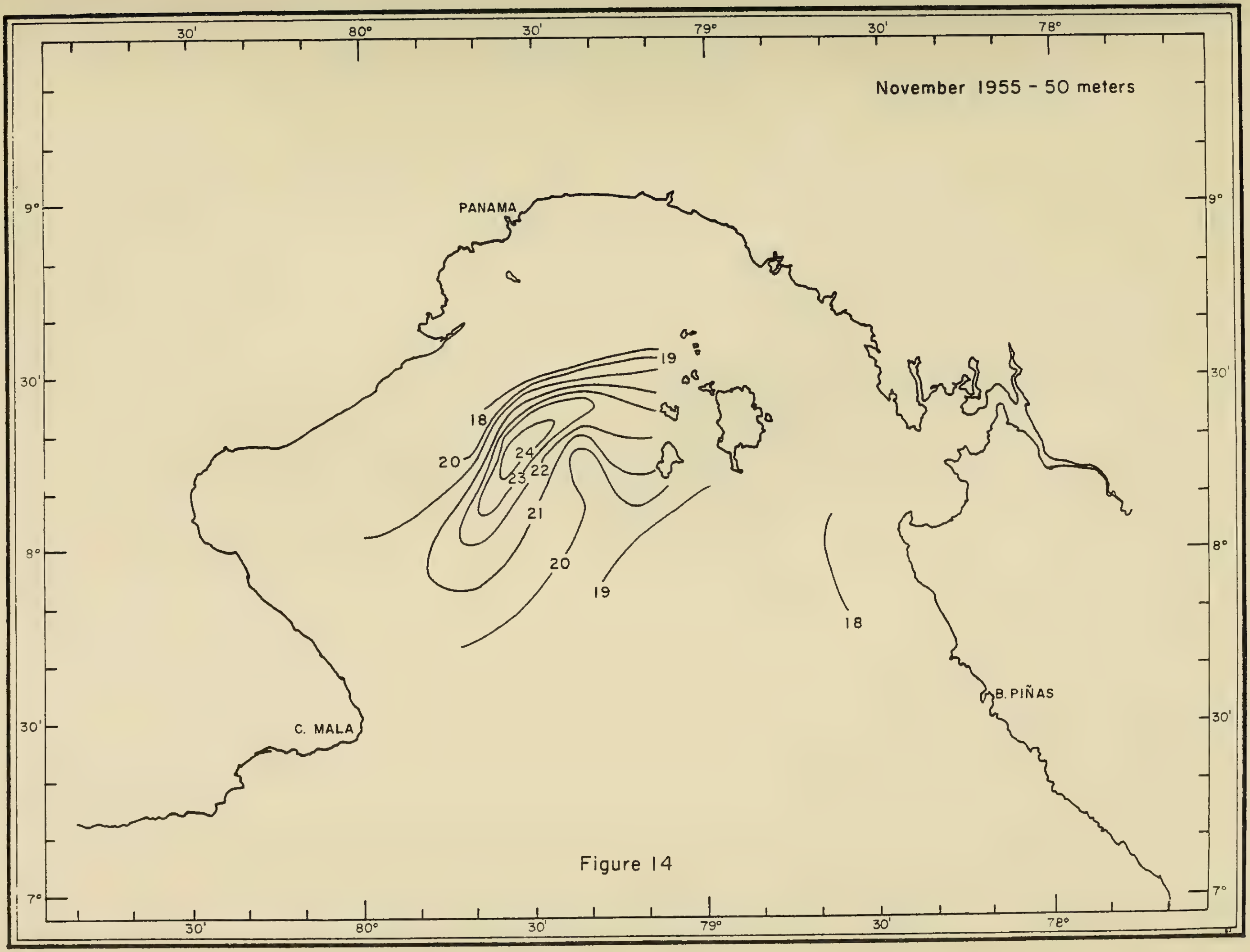

November 1955 - 50 meters
PANAMA
C. MALA
B. PIÑAS
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
18
19
20
21
22
23
24
20
19
18

Figure 14

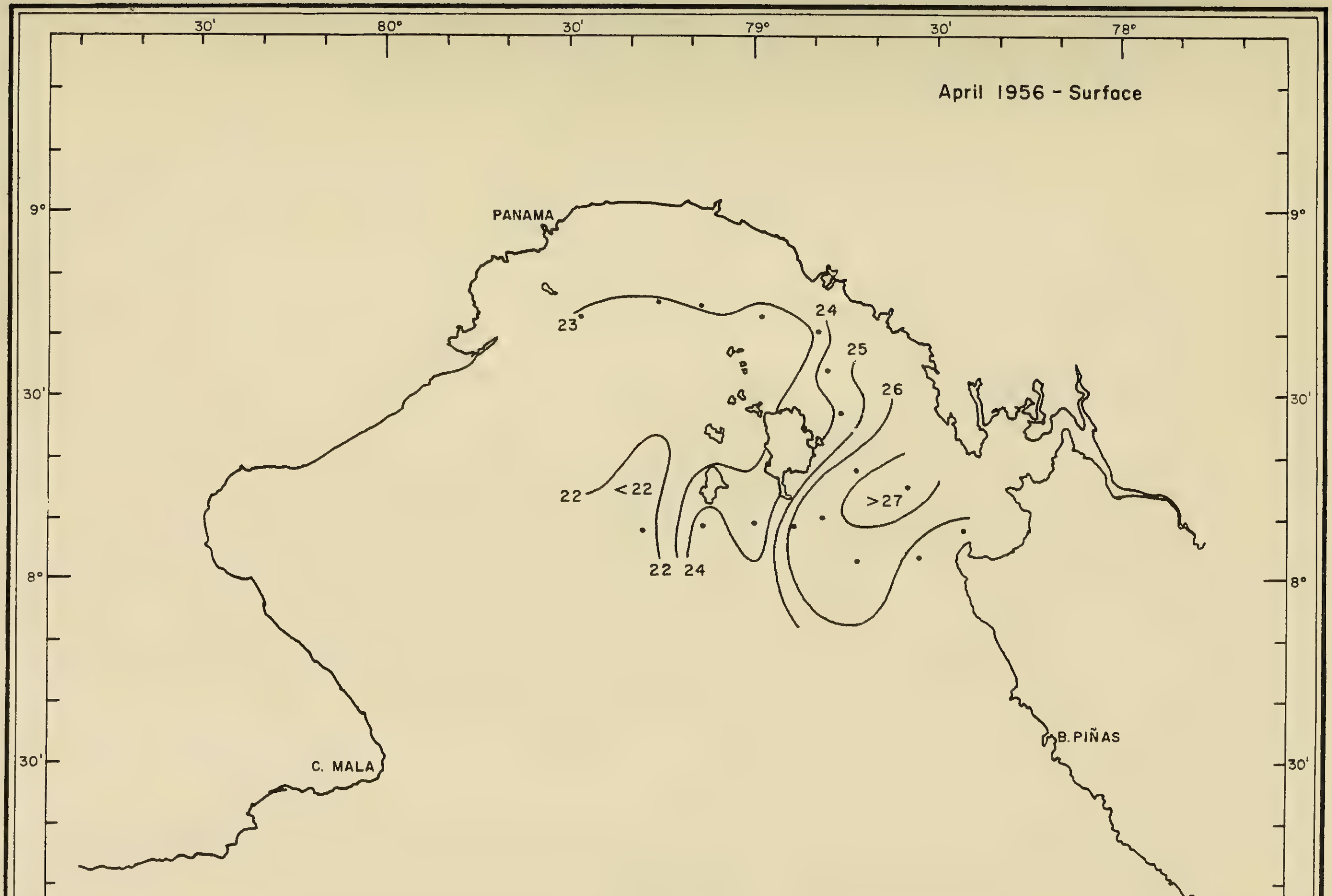
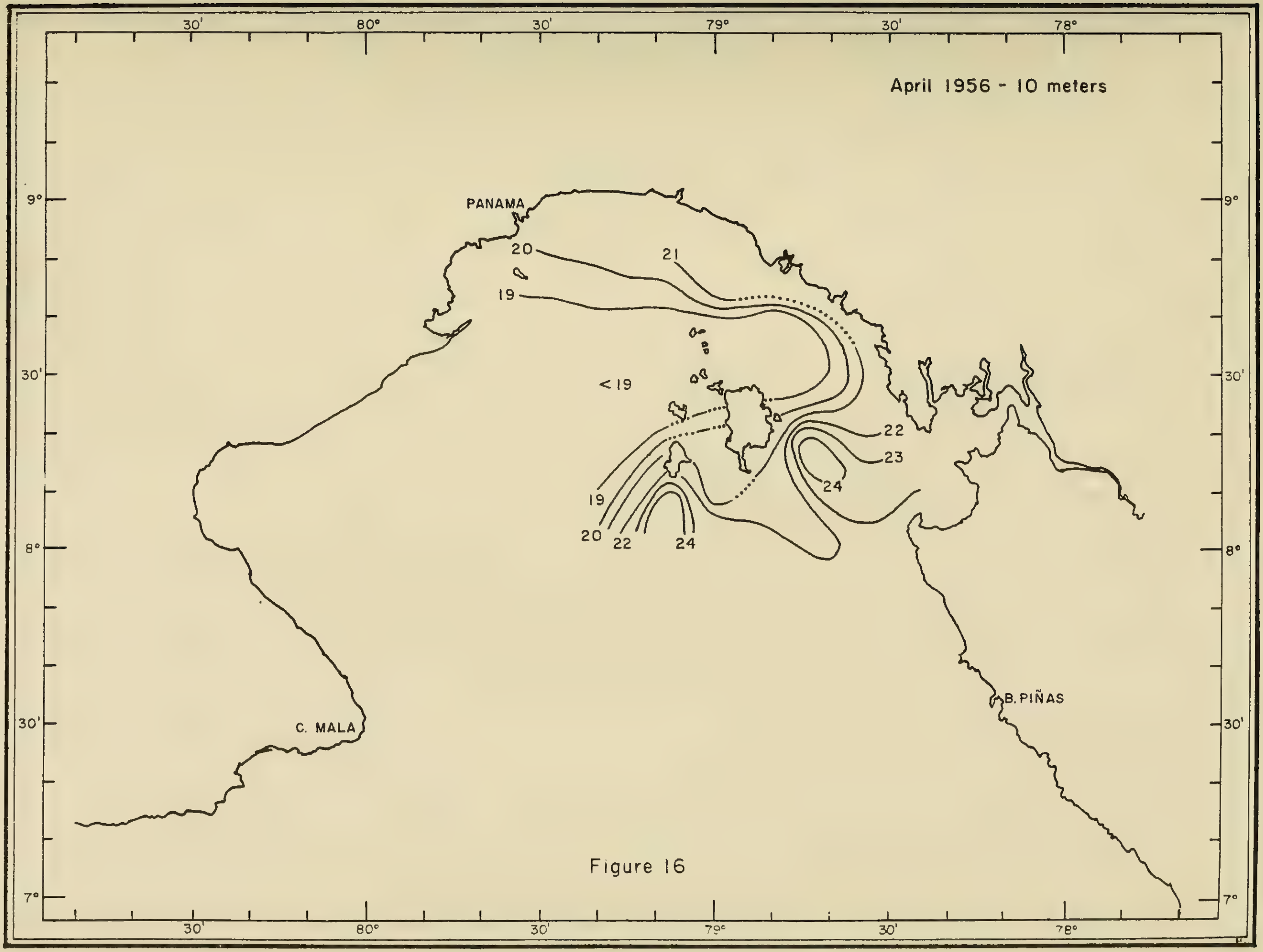

April 1956 - Surface
PANAMA
C. MALA
B. PIÑAS
23
24
25
26
>27
22
<22
22
24
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 15


April 1956 - 10 meters
PANAMA
C. MALA
B. PIÑAS
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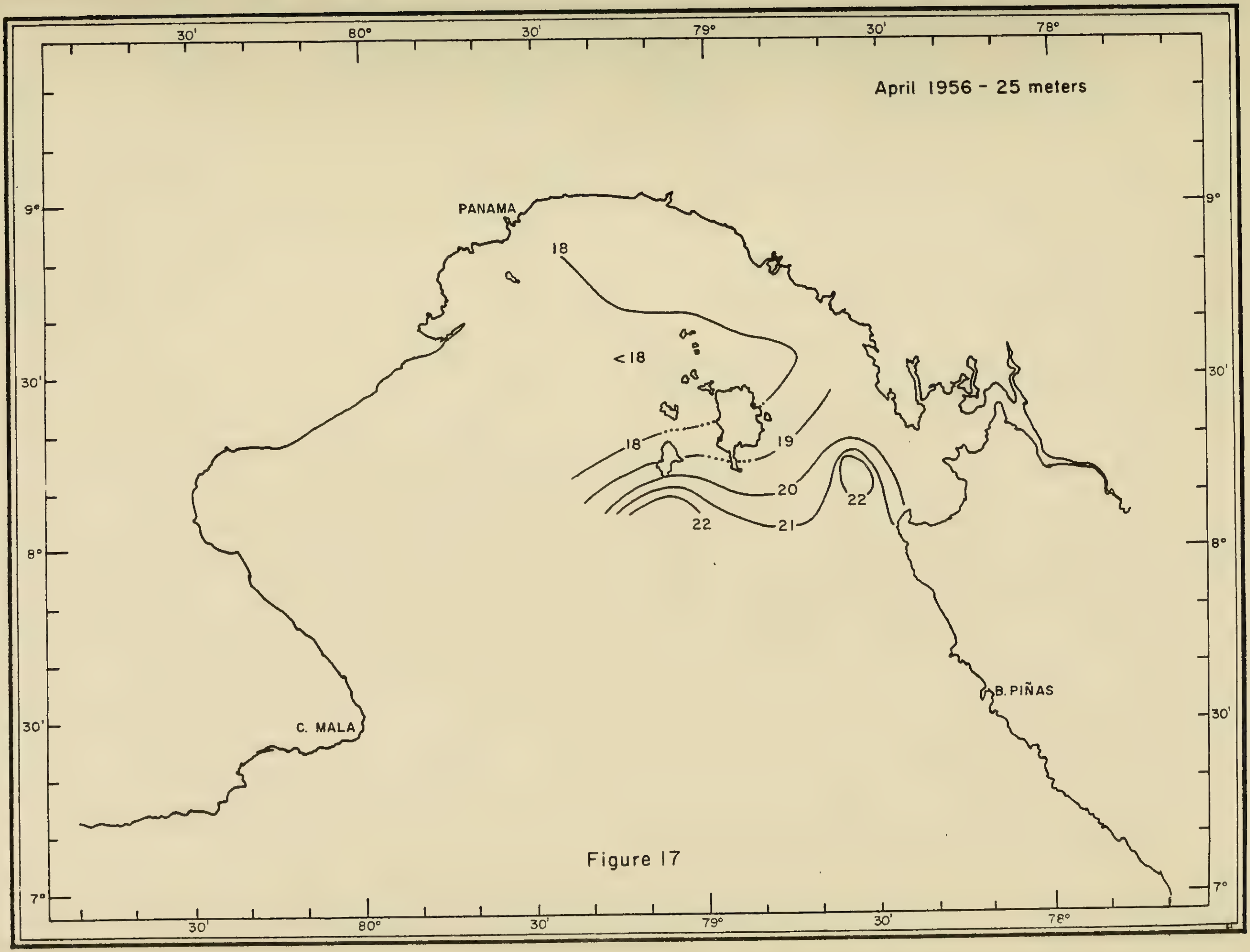
19
20
21
22
23
24
9°
30'
8°
7°
80°
79°
78°
Figure 16


April 1956 - 25 meters
PANAMA
C. MALA
B. PIÑAS
18
<18
18
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20
21
22
22
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 17

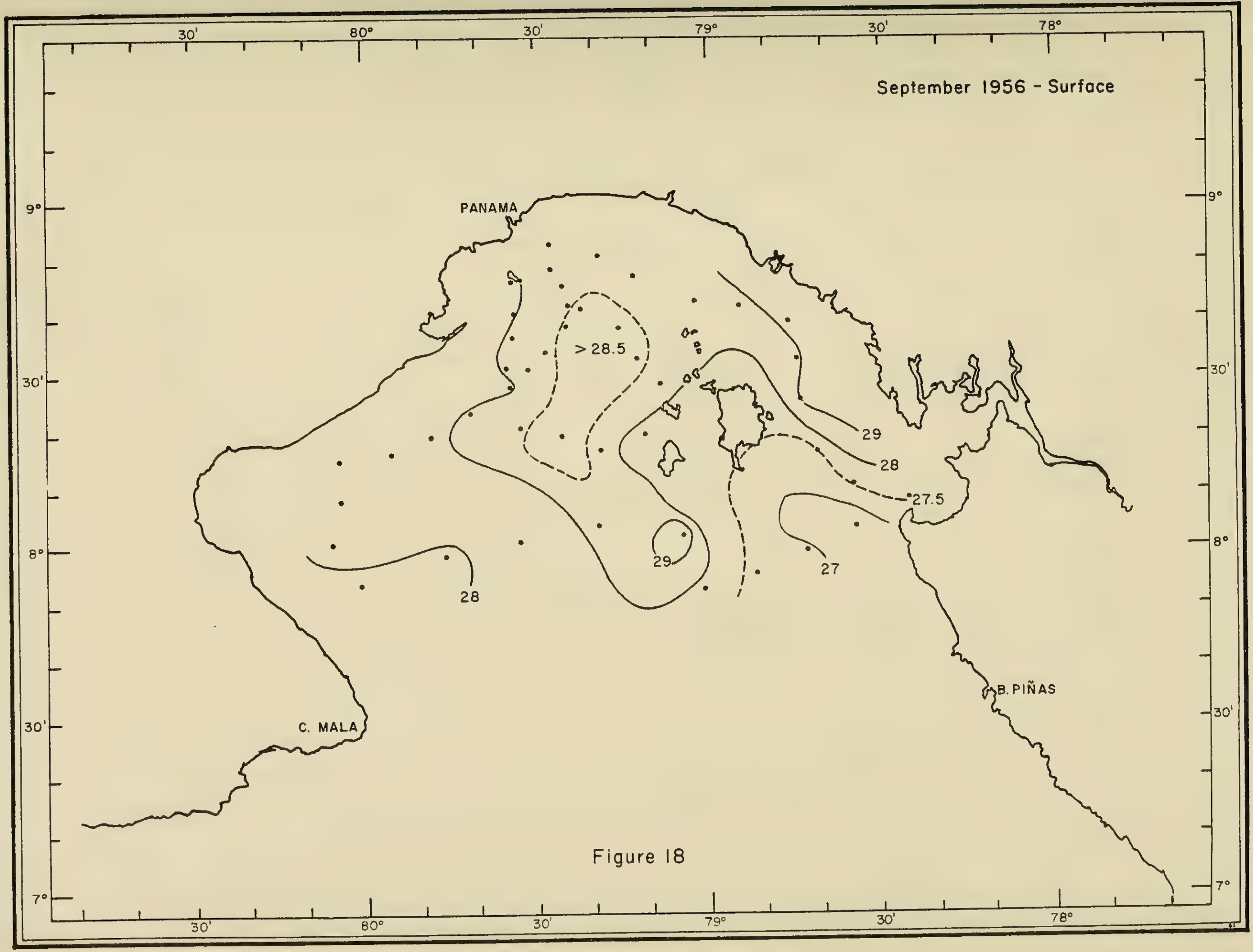
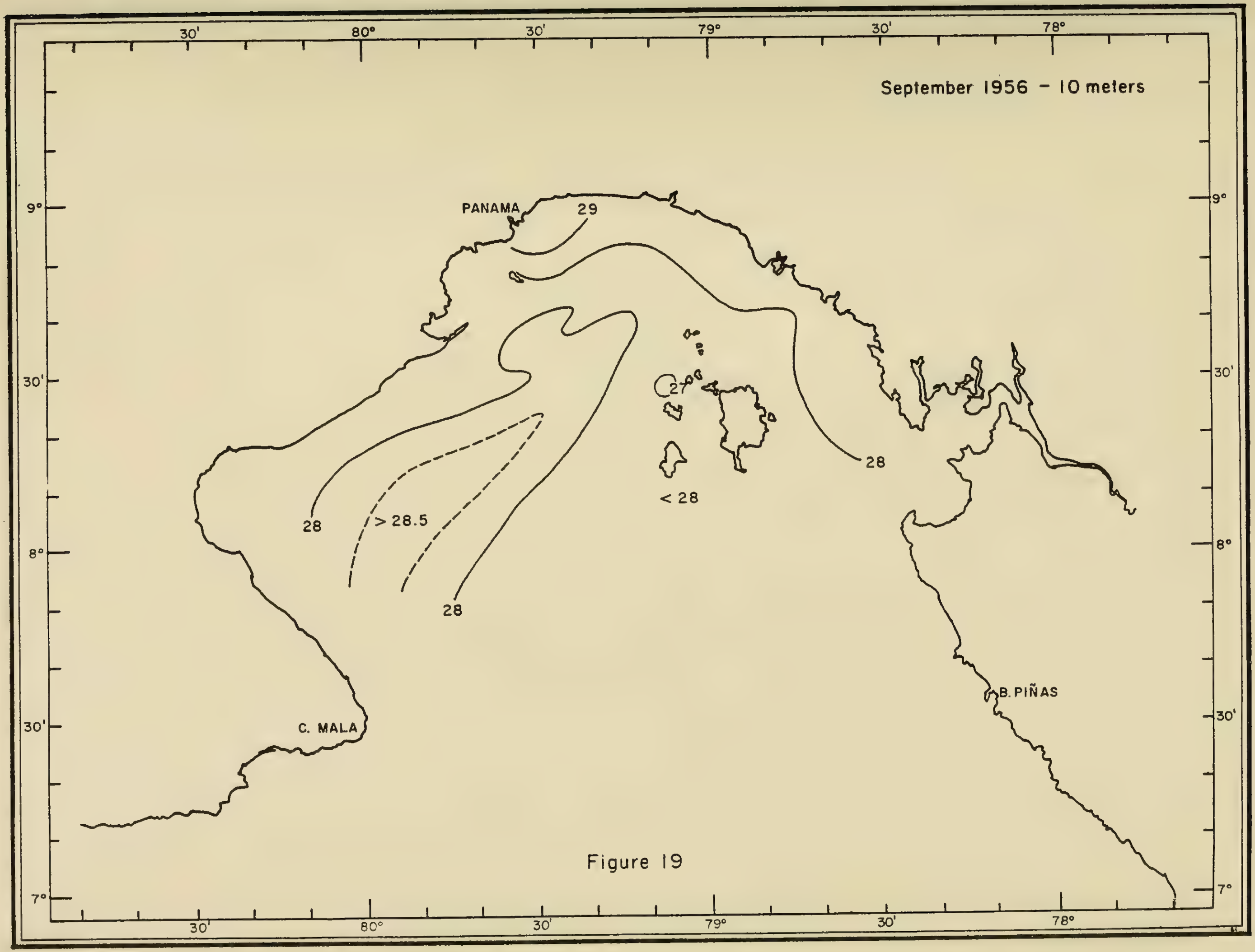

September 1956 - Surface
PANAMA
C. MALA
B. PIÑAS
> 28.5
29
28
27.5
27
29
28
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 18



September 1956 - 10 meters
PANAMA
29
28
27
< 28
> 28.5
28
28
C. MALA
B. PIÑAS
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 19

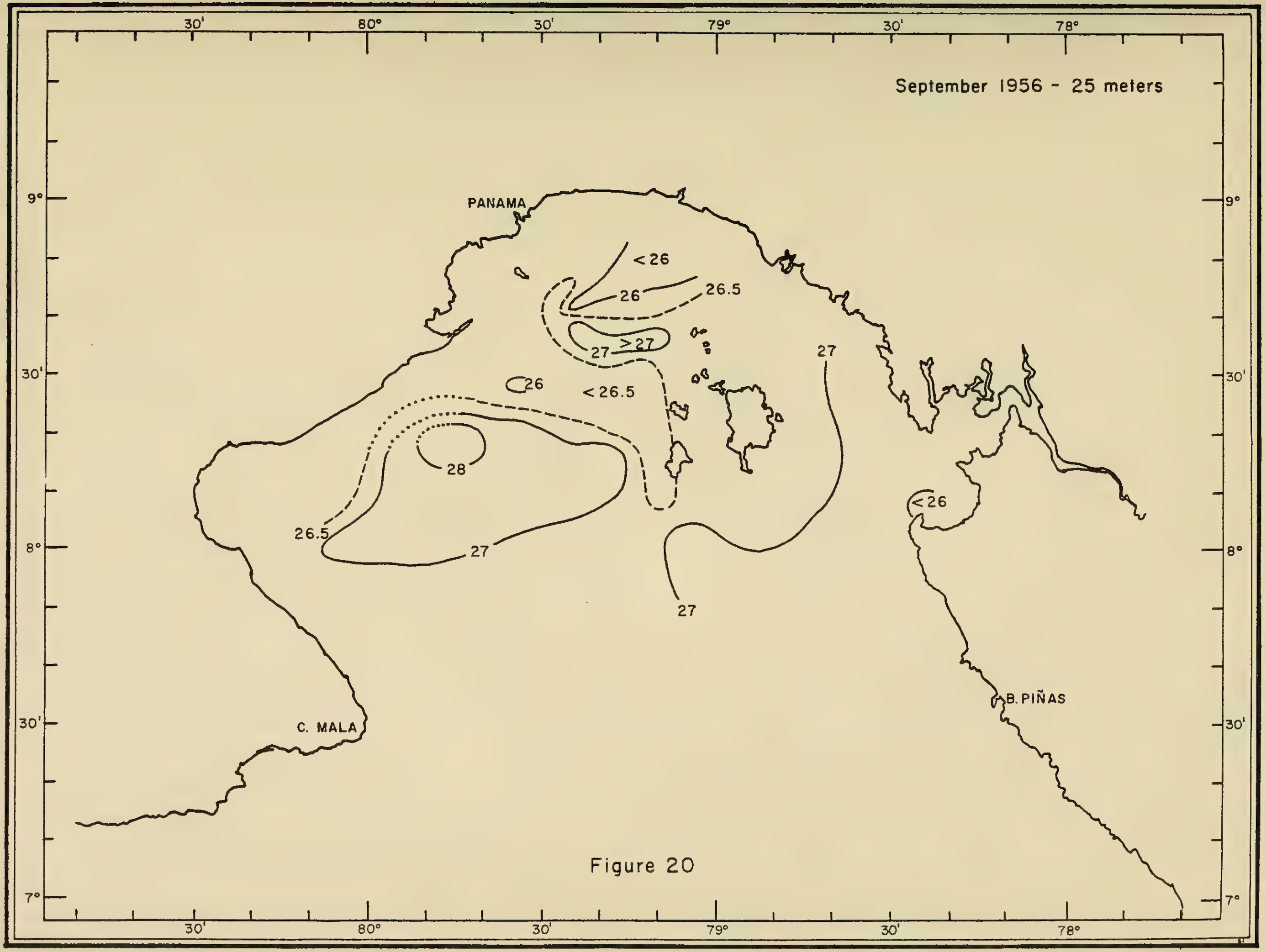

September 1956 - 25 meters
PANAMA
C. MALA
B. PIÑAS
< 26
26
26.5
27
> 27
< 26.5
28
30'
80°
79°
78°
9°
8°
7°

Figure 20

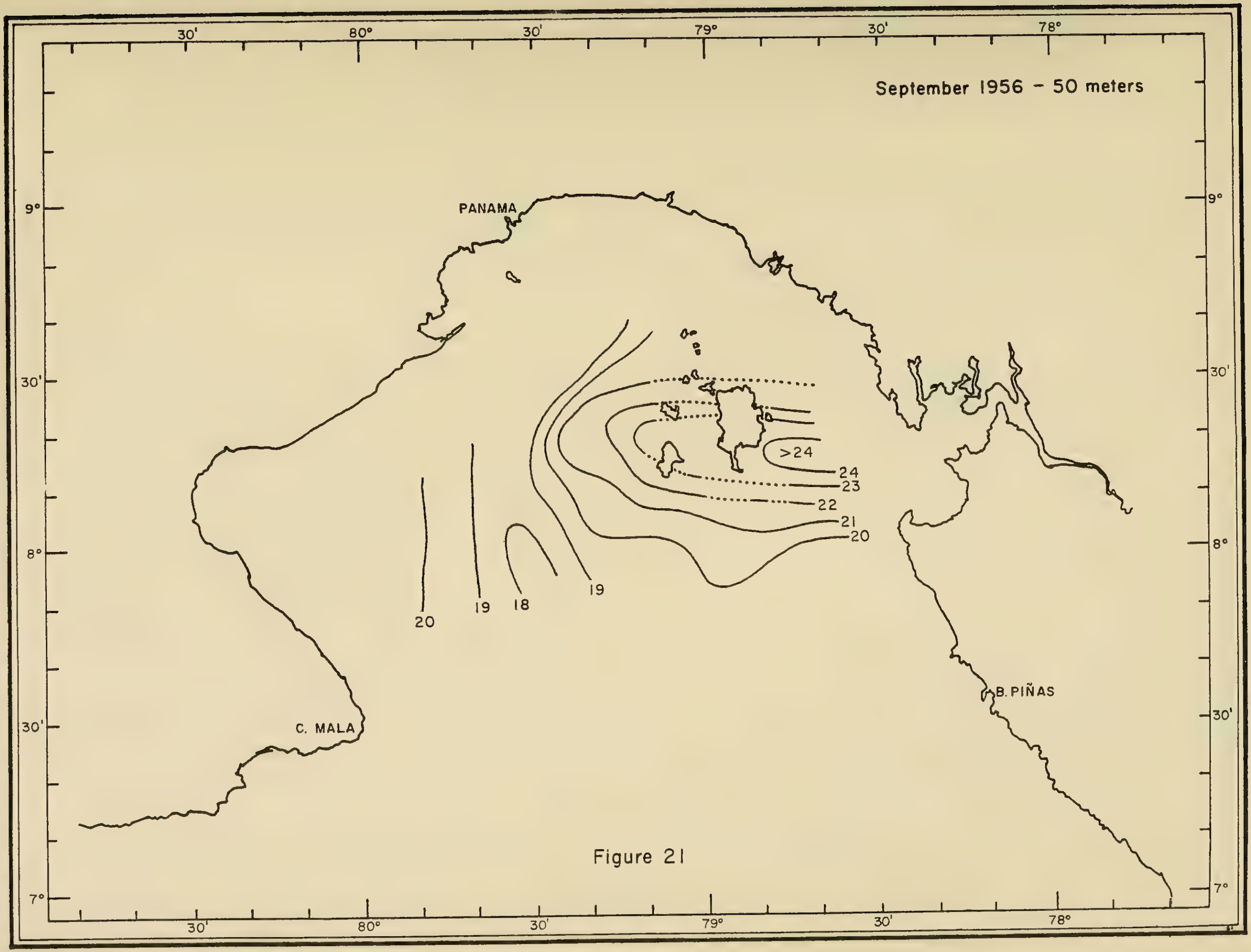

September 1956 – 50 meters
PANAMA
C. MALA
B. PIÑAS
>24
24
23
22
21
20
19
18
19
20
9°
30'
8°
30'
7°
30'
80°
30'
79°
30'
78°

Figure 21

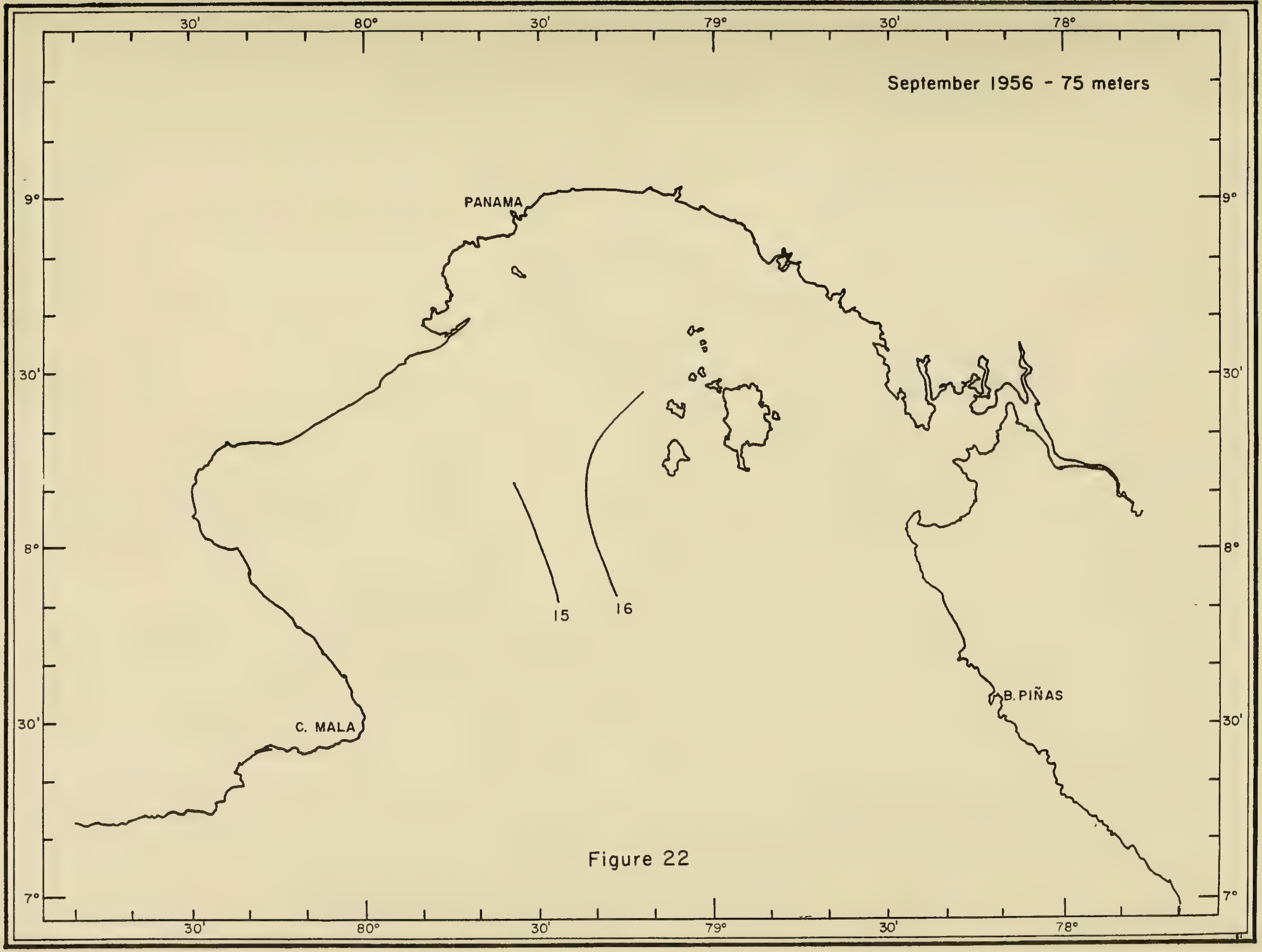
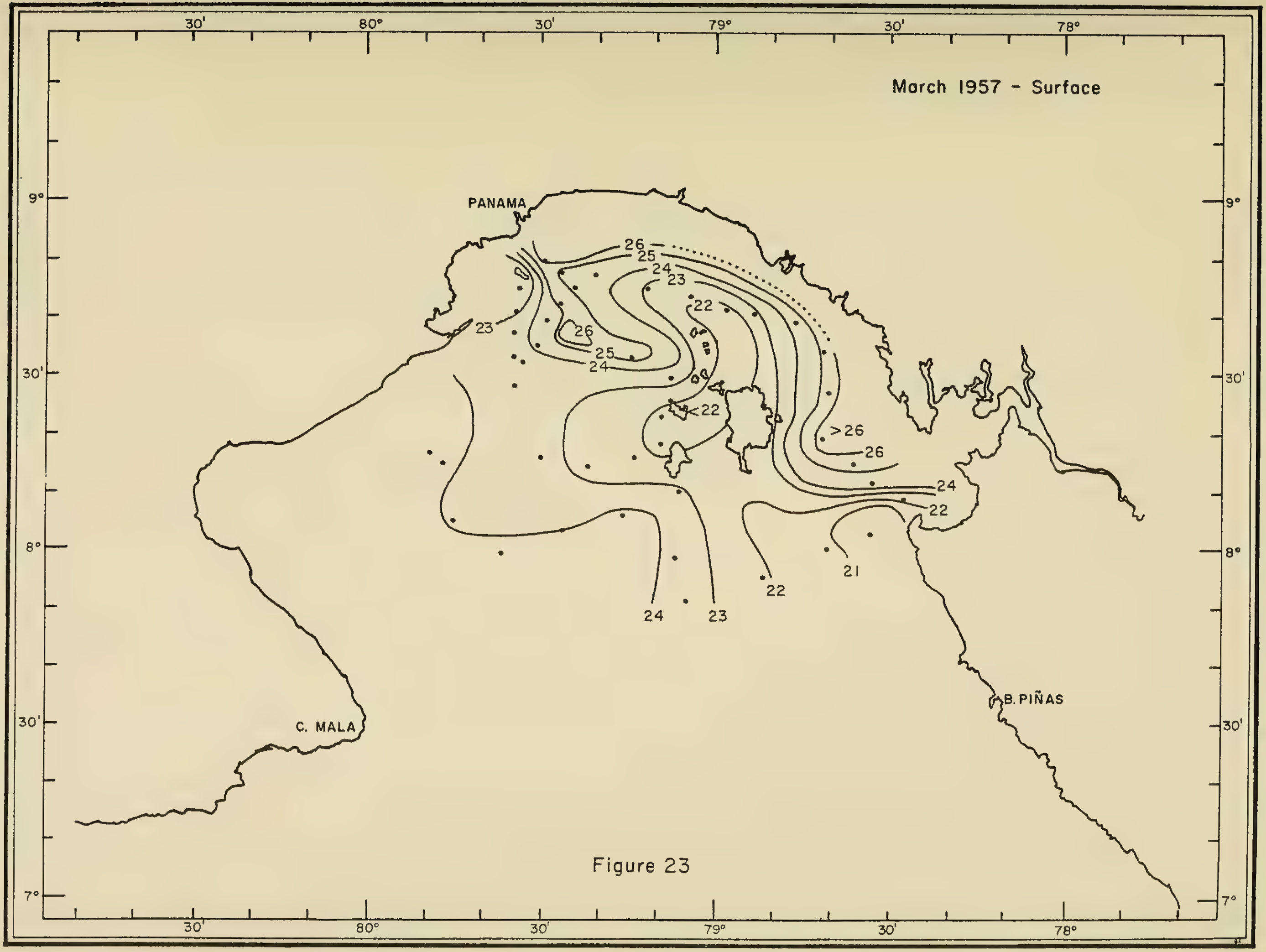

September 1956 - 75 meters
PANAMA
C. MALA
B. PIÑAS
15
16
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 22



March 1957 - Surface
PANAMA
C. MALA
B. PIÑAS
26
25
24
23
22
26
25
24
23
>26
26
24
22
22
21
22
24
23
9°
30'
8°
30'
7°
30'
80°
30'
79°
30'
78°

Figure 23

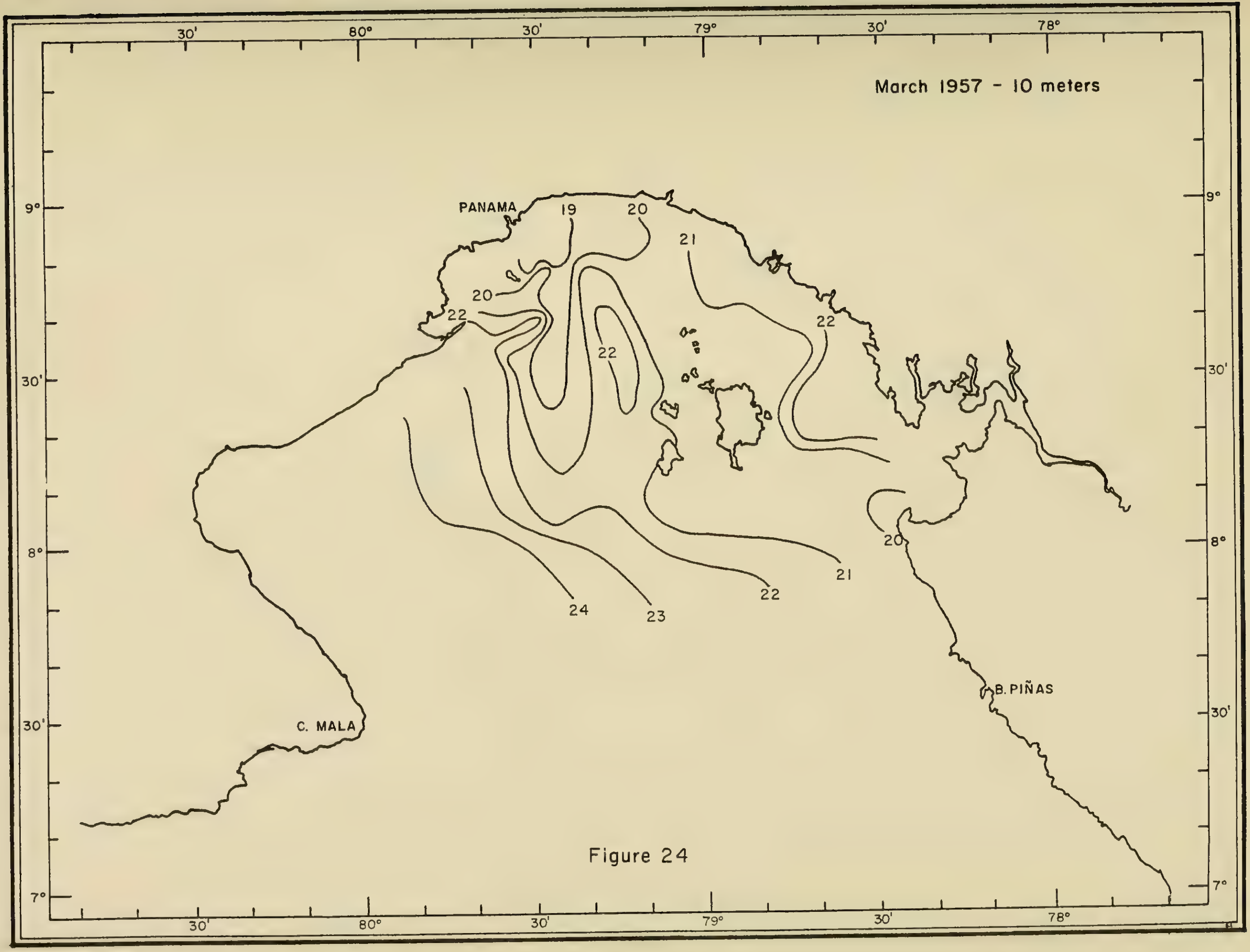

March 1957 - 10 meters
PANAMA
C. MALA
B. PIÑAS
19
20
20
20
21
21
22
22
22
22
22
23
24
9°
30'
8°
30'
7°
30'
80°
30'
79°
30'
78°

Figure 24

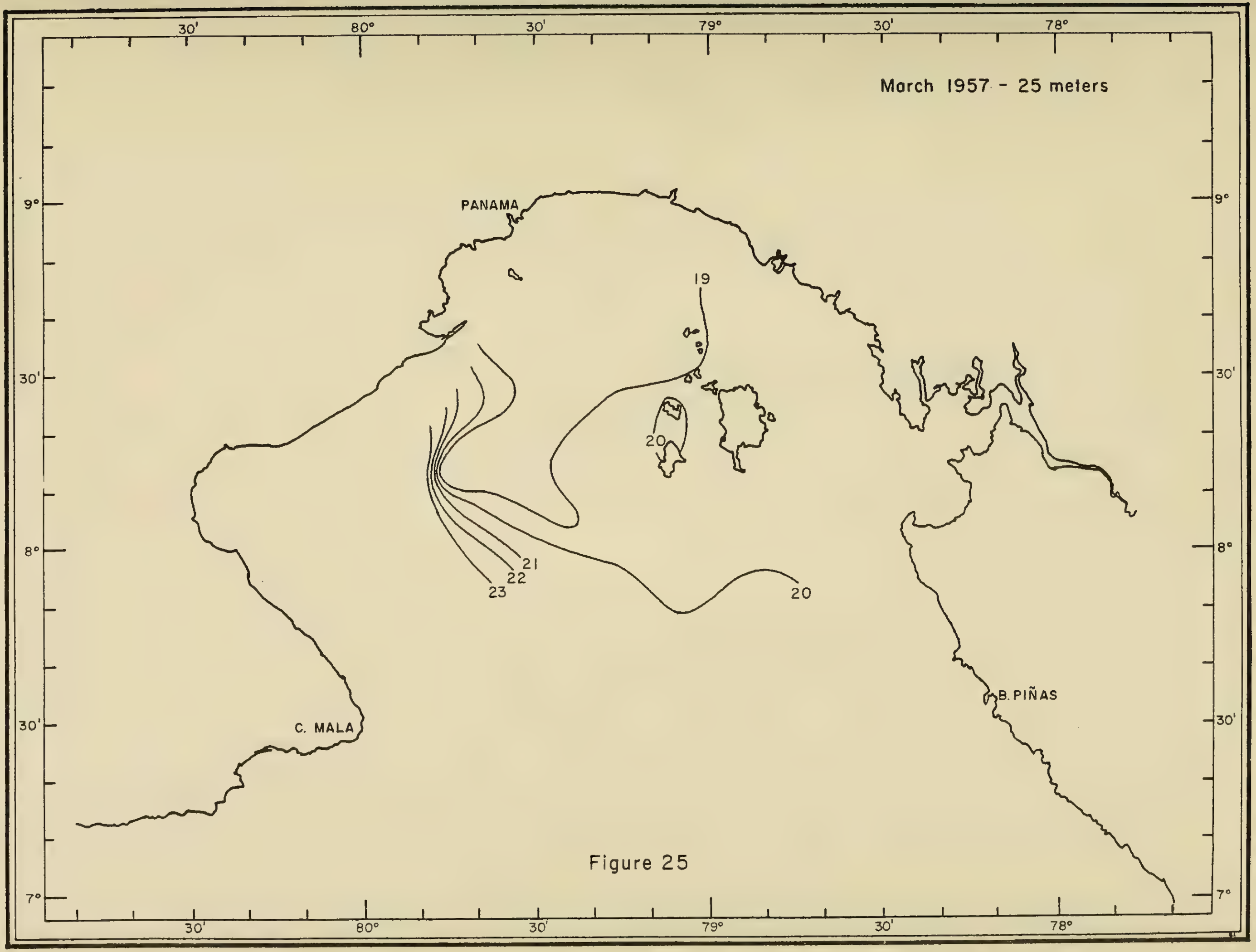

March 1957 - 25 meters
PANAMA
C. MALA
B. PIÑAS
19
20
20
21
22
23
9°
30'
8°
30'
7°
30'
80°
30'
79°
30'
78°

Figure 25

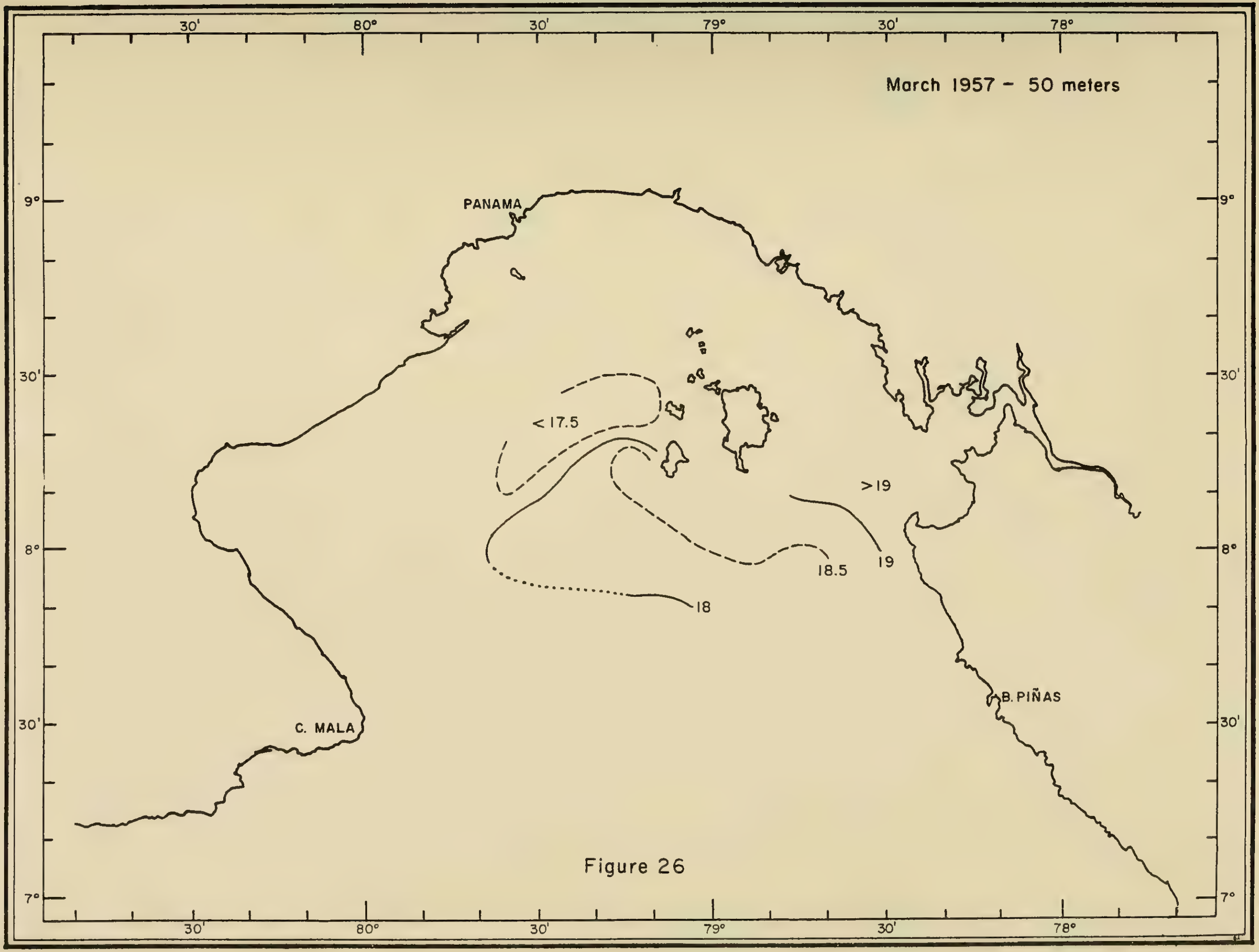

March 1957 - 50 meters
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
PANAMA
C. MALA
B. PIÑAS
< 17.5
18
18.5
19
>19

Figure 26

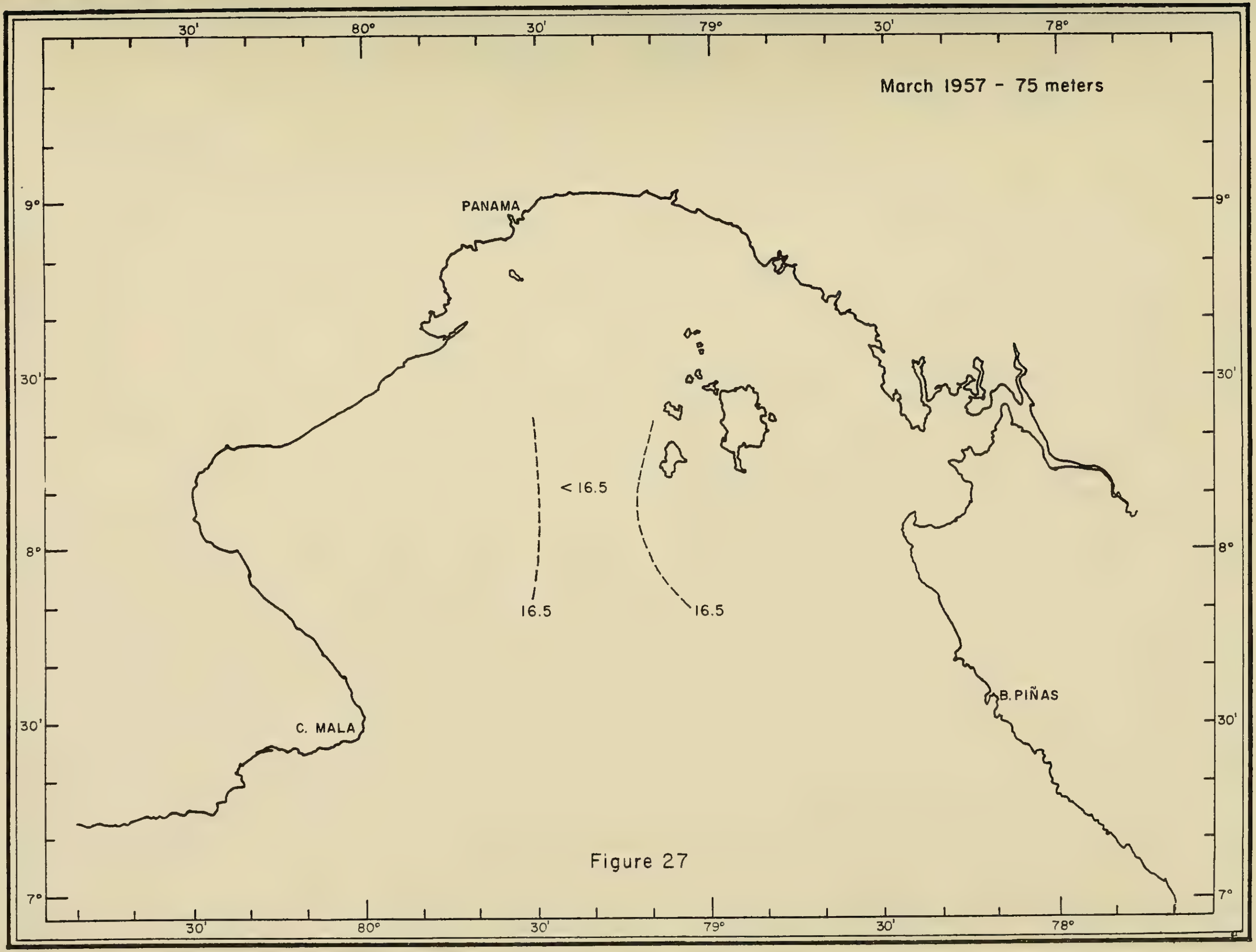

March 1957 - 75 meters
PANAMA
C. MALA
B. PIÑAS
< 16.5
16.5
16.5
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 27

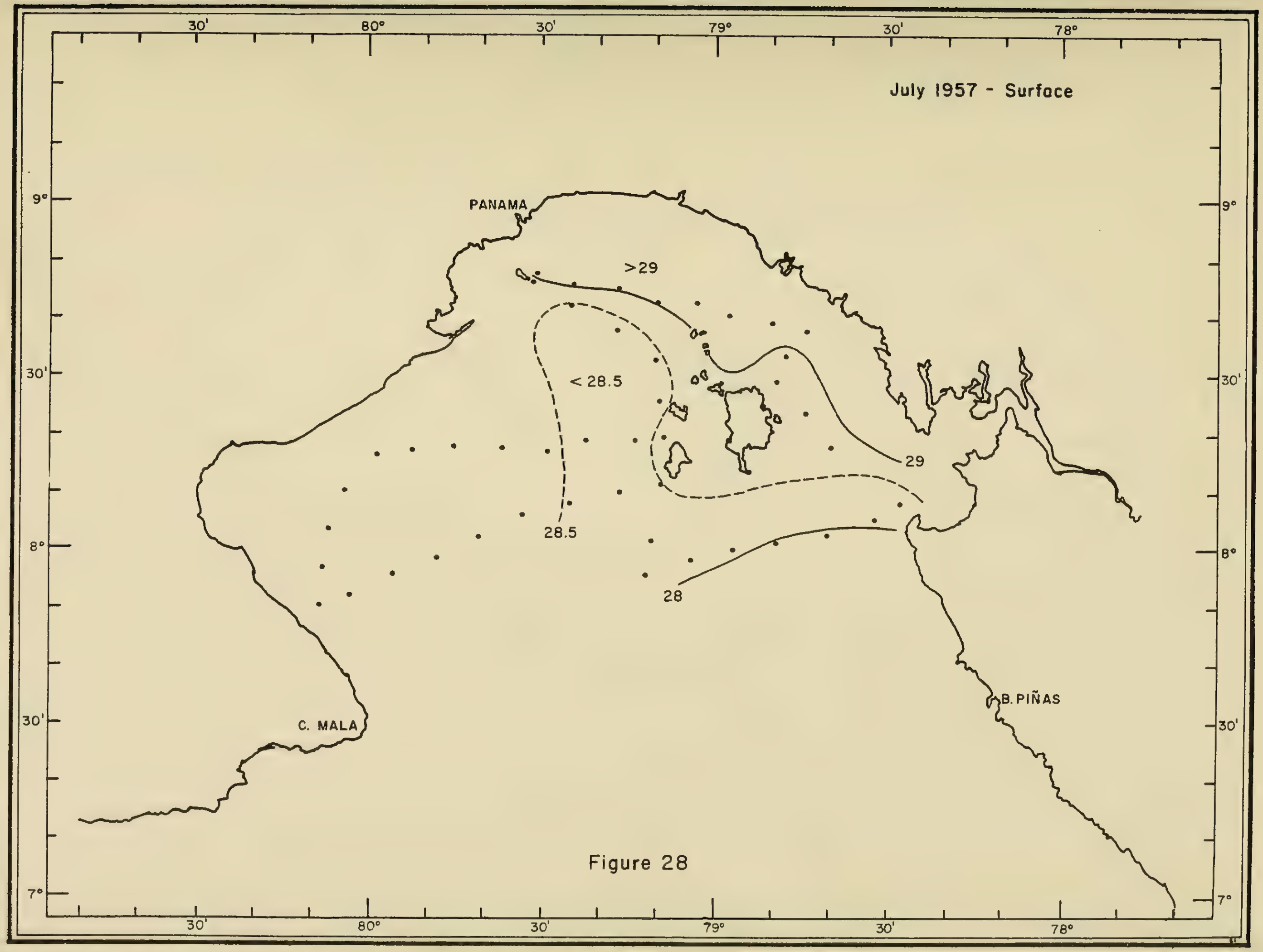

July 1957 - Surface
PANAMA
>29
< 28.5
29
28.5
28
C. MALA
B. PIÑAS
30'
80°
79°
78°
9°
8°
7°

Figure 28

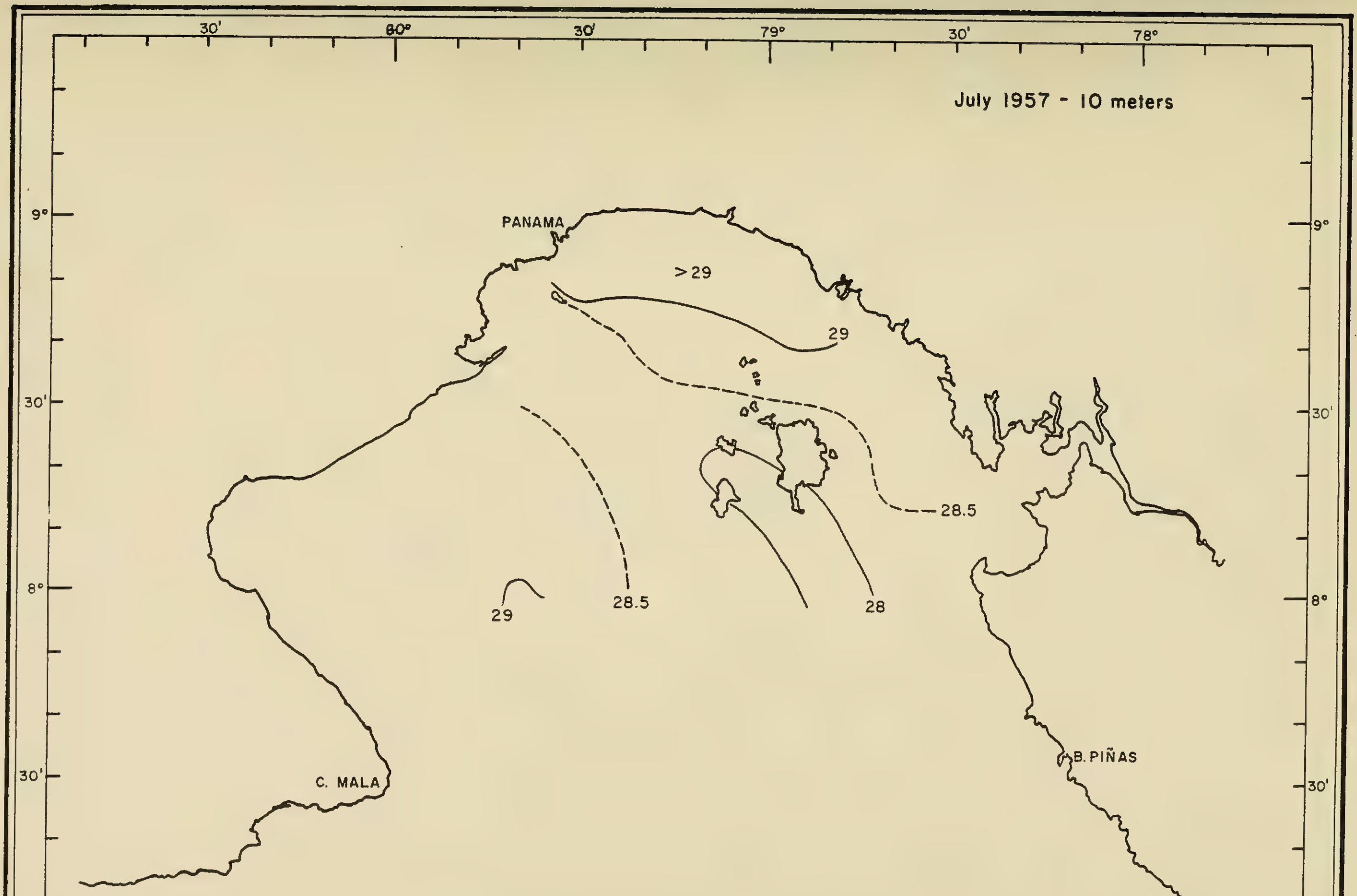
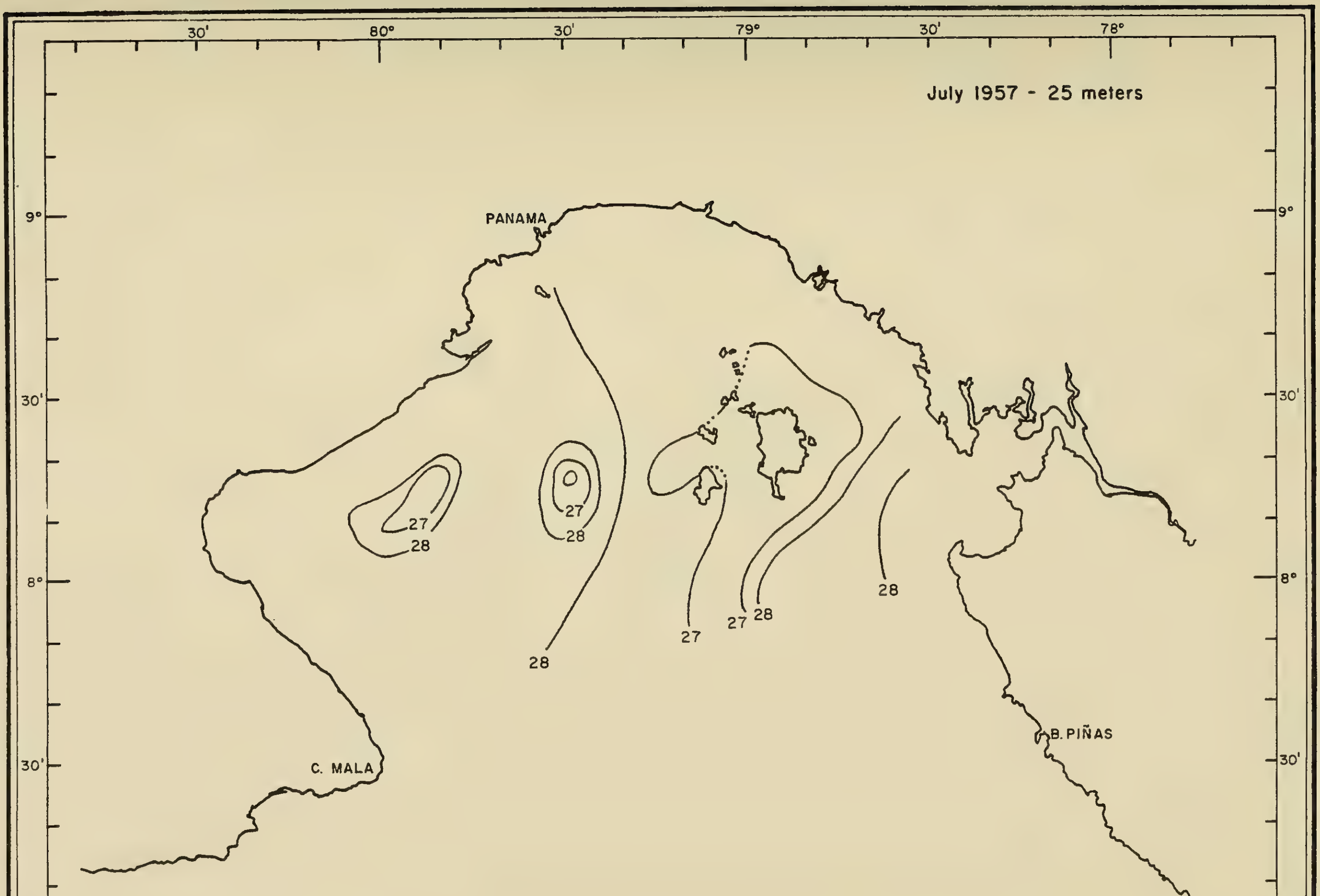
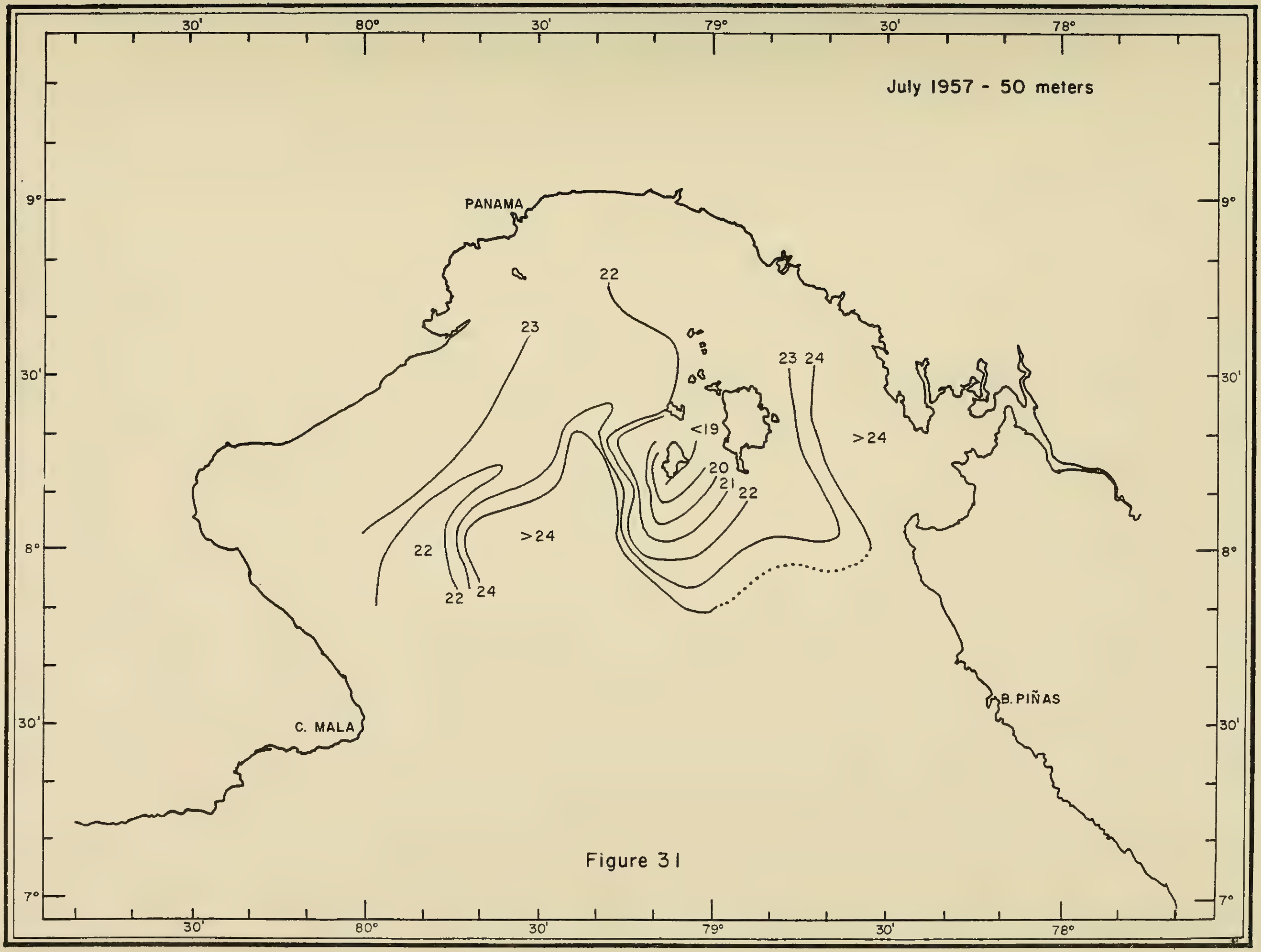

July 1957 - 10 meters
PANAMA
>29
29
28.5
28
28.5
29
C. MALA
B. PIÑAS
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 29



July 1957 - 25 meters
PANAMA
C. MALA
B. PIÑAS
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
27
28
27
28
27
27
28
28
28

Figure 30



July 1957 - 50 meters
PANAMA
C. MALA
B. PIÑAS
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
22
23
23 24
>24
<19
20
21
22
>24
22
22
24

Figure 31

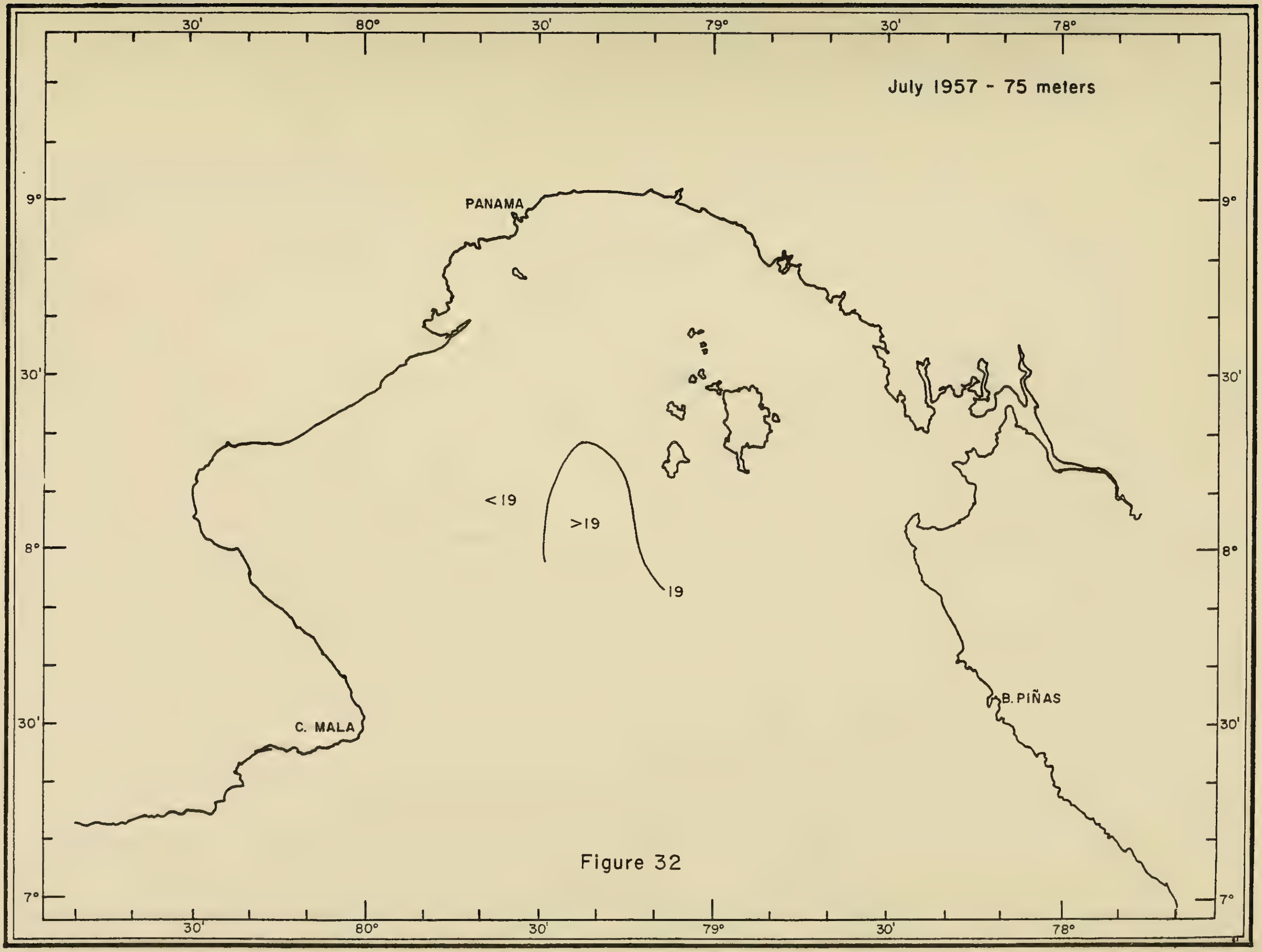

July 1957 - 75 meters
PANAMA
C. MALA
B. PIÑAS
<19
>19
19
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 32

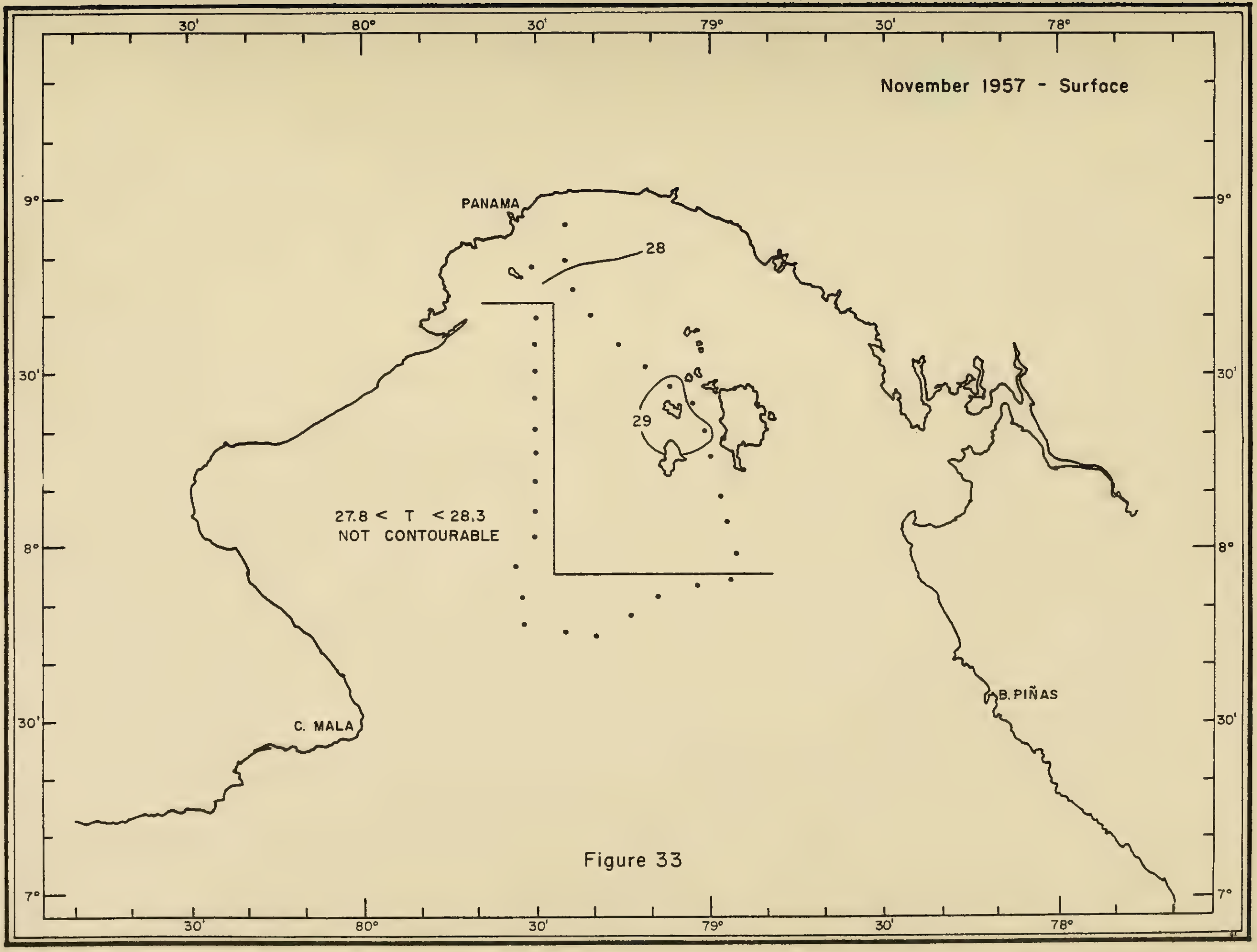

November 1957 - Surface
PANAMA
28
29
27.8 < T < 28.3
NOT CONTOURABLE
C. MALA
B. PIÑAS
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 33

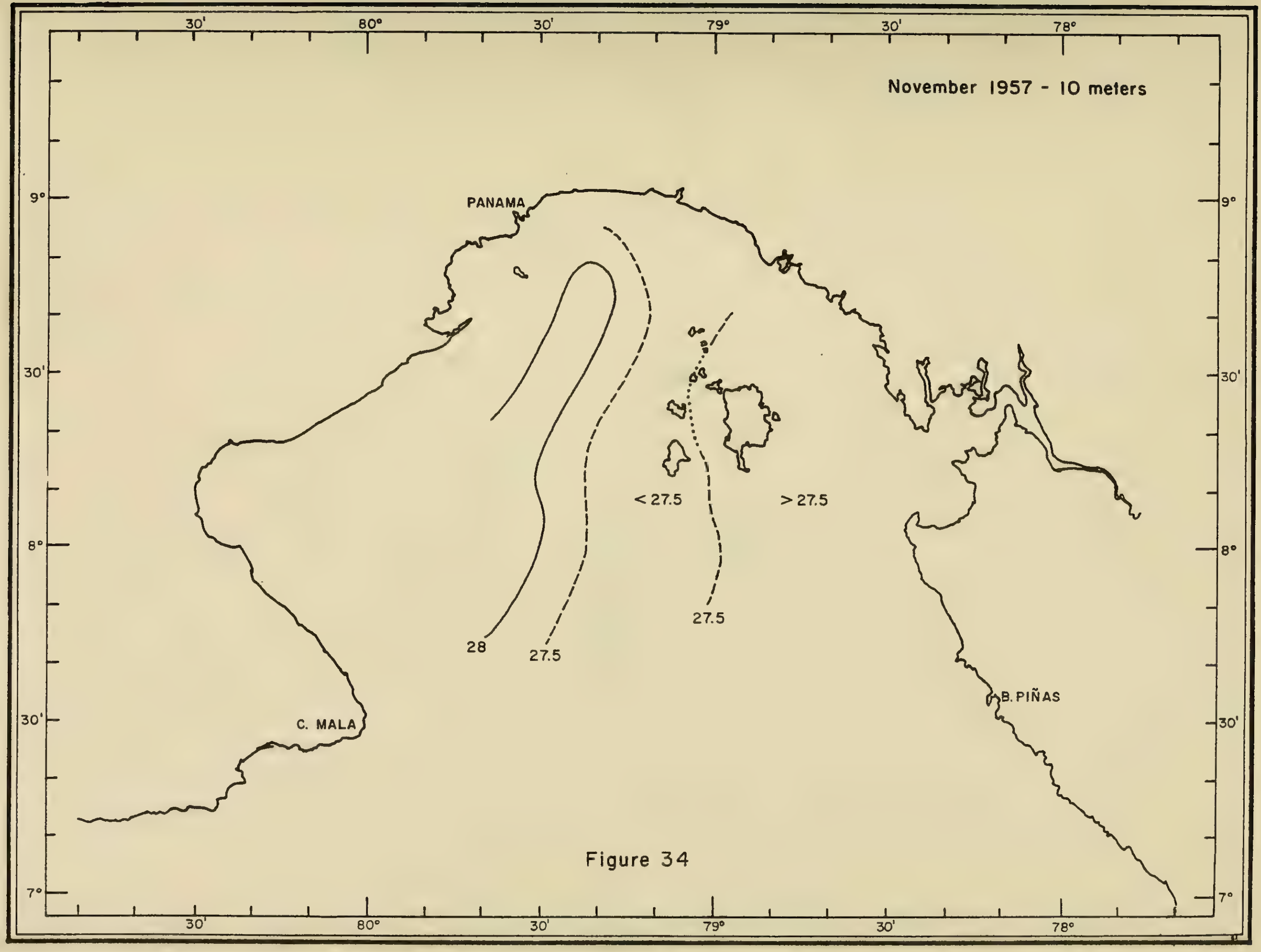

November 1957 - 10 meters
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
PANAMA
C. MALA
B. PIÑAS
28
27.5
27.5
< 27.5
> 27.5

Figure 34

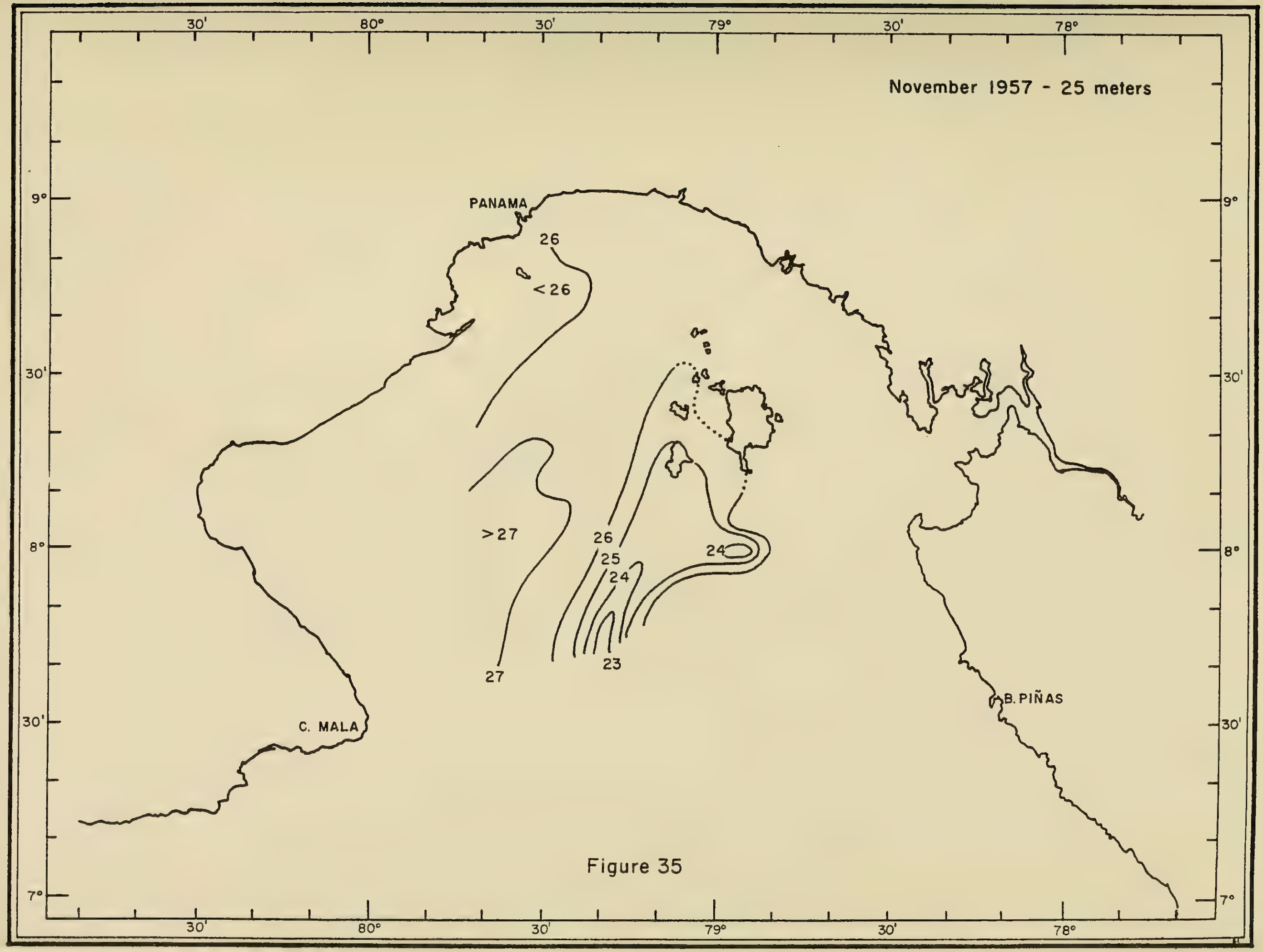
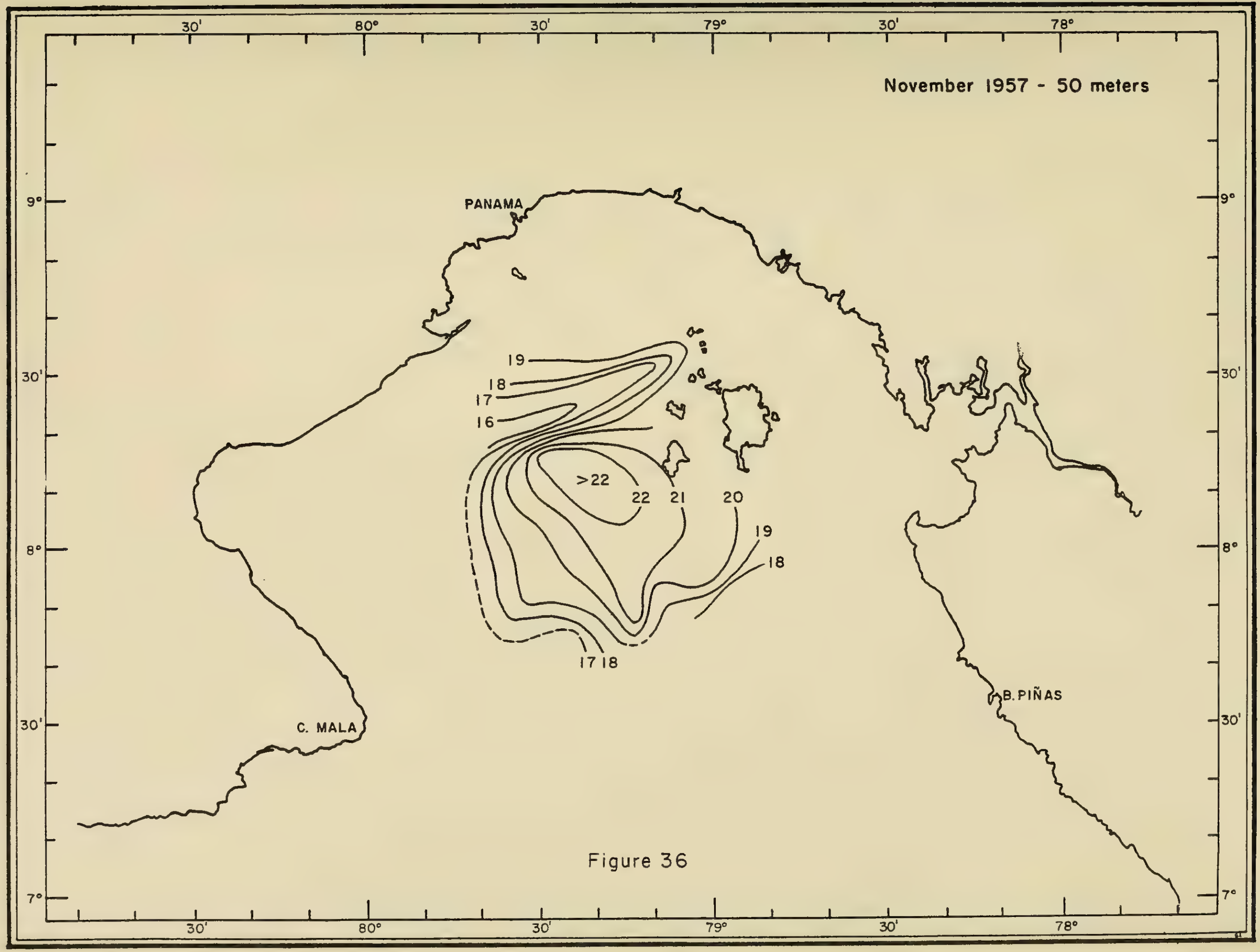

November 1957 - 25 meters
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
PANAMA
26
<26
>27
27
26
25
24
23
24
C. MALA
B. PIÑAS

Figure 35



November 1957 - 50 meters
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
PANAMA
C. MALA
B. PIÑAS
19
18
17
16
>22
22
21
20
19
18
17
18

Figure 36

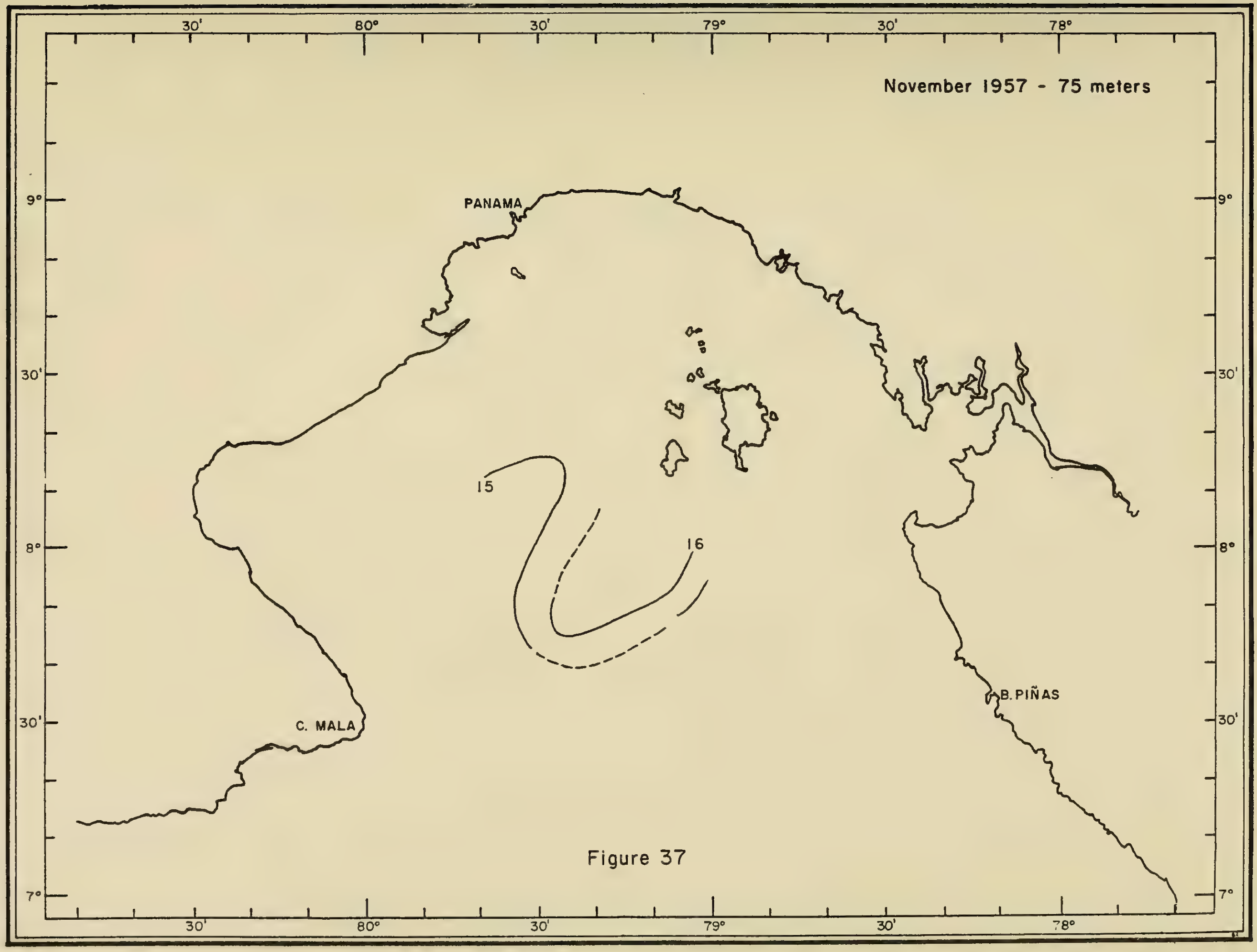

November 1957 - 75 meters
PANAMA
C. MALA
B. PIÑAS
15
16
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 37

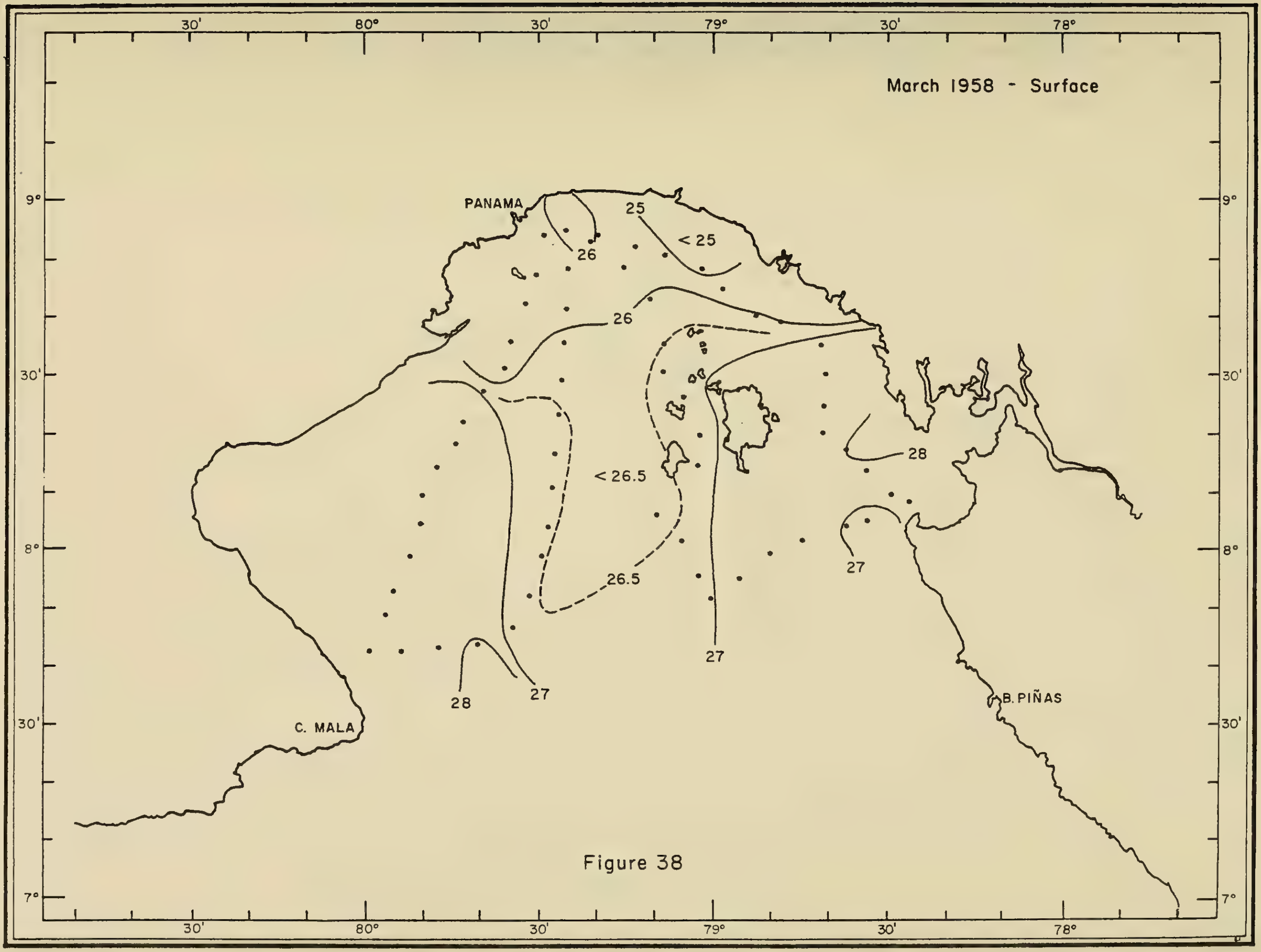
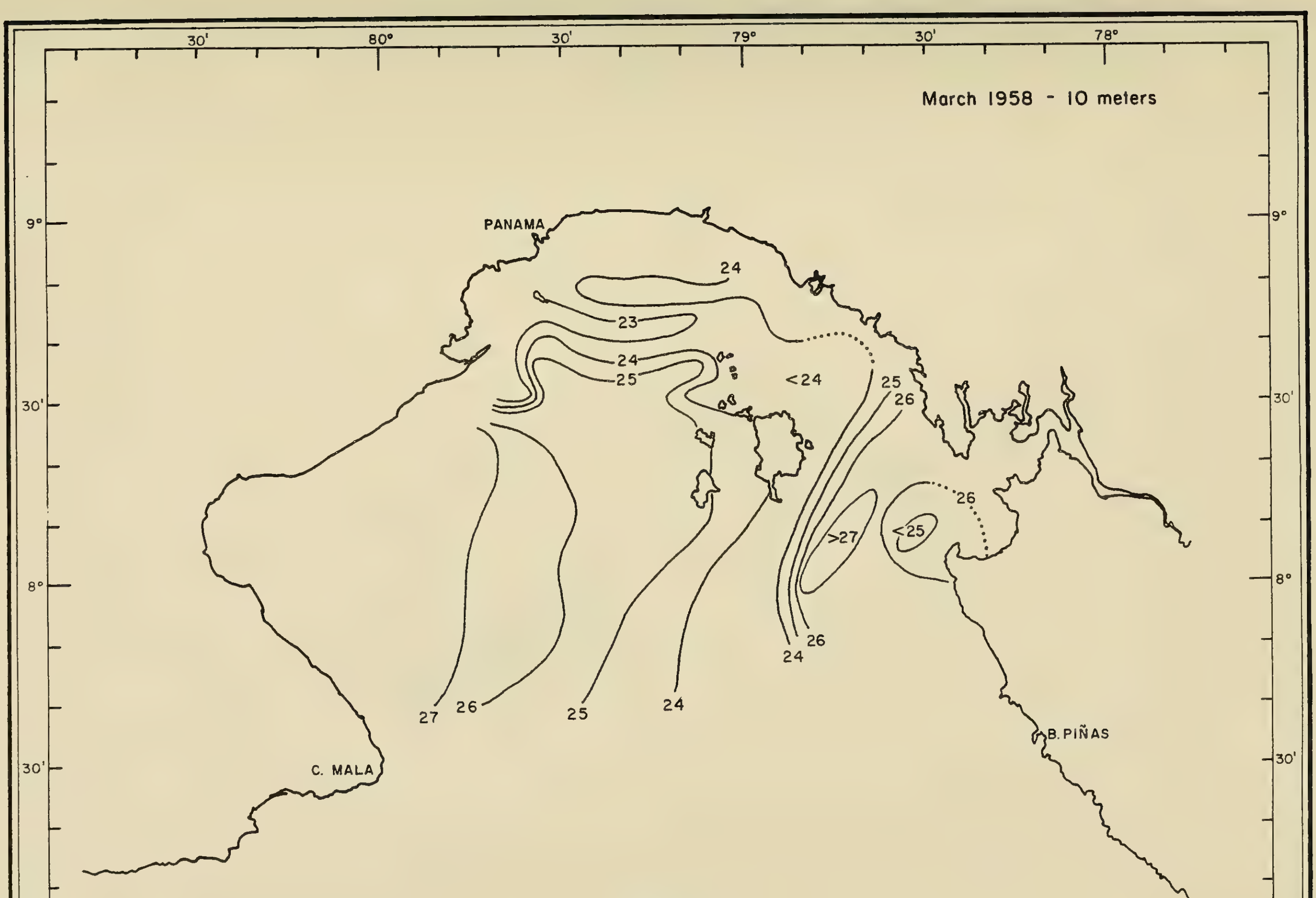
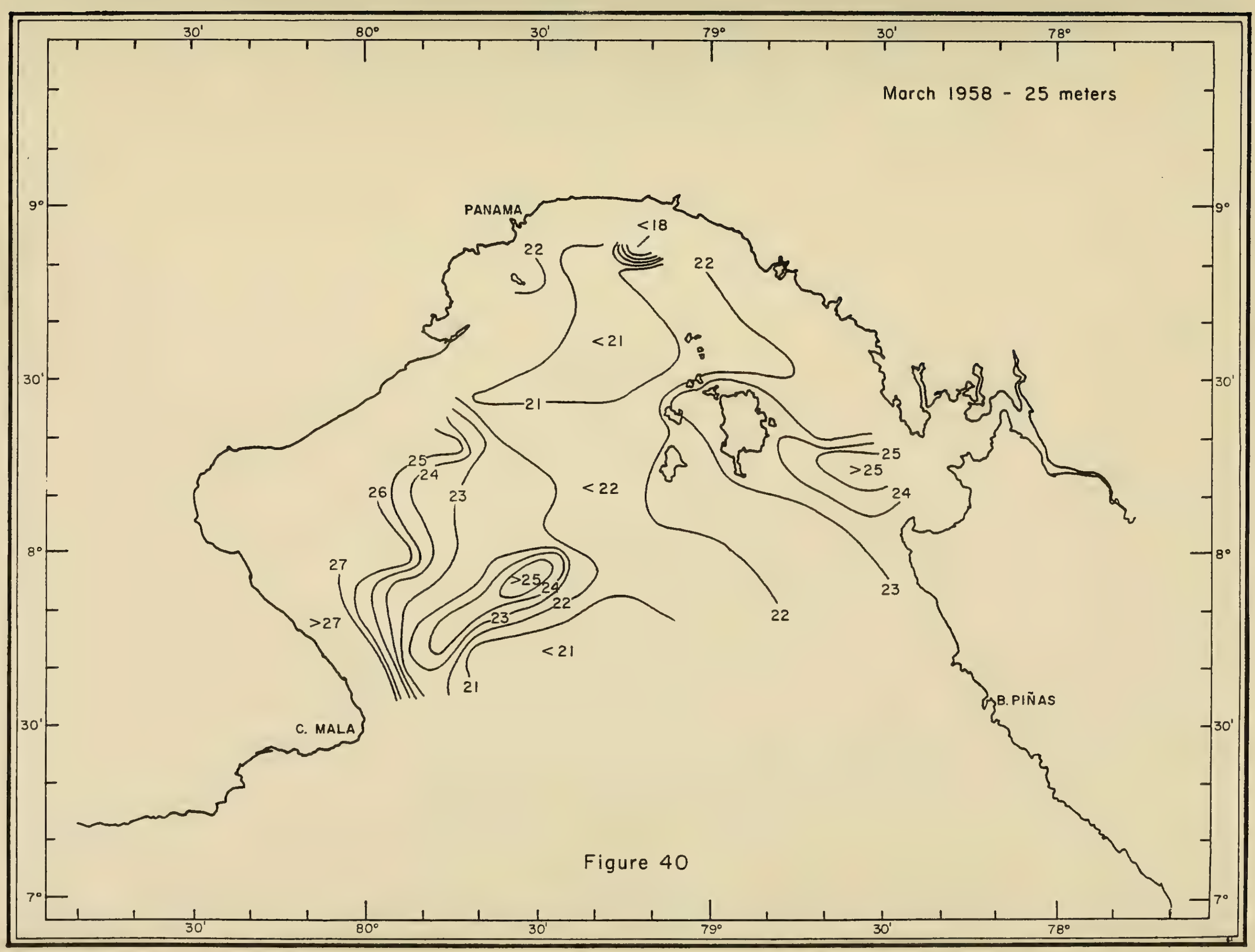

March 1958 - Surface
PANAMA
C. MALA
B. PIÑAS
< 25
25
26
26
< 26.5
26.5
27
27
27
28
28
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

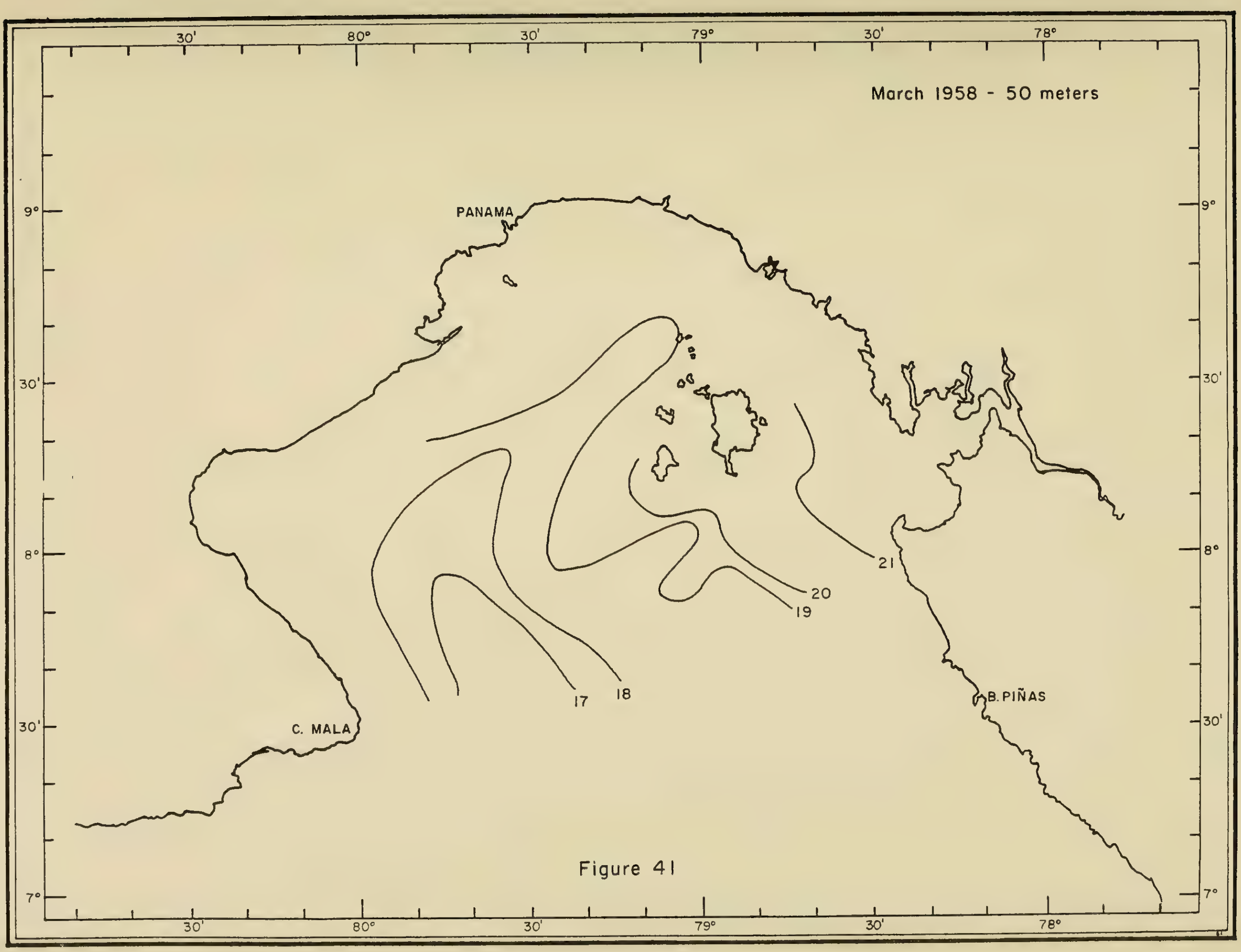
Figure 38



March 1958 - 10 meters
PANAMA
C. MALA
B. PIÑAS
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
24
23
24
25
<24
25
26
>27
26
<25
27
26
25
24
26
24

Figure 39


March 1958 - 25 meters
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
PANAMA
C. MALA
B. PIÑAS
<18
22
<21
21
<22
25
>25
24
23
26
27
>27
>25
24
22
23
<21
21
22
25
>25
24
23
22
Figure 40



March 1958 - 50 meters
PANAMA
C. MALA
B. PIÑAS
17
18
19
20
21
9°
30'
8°
7°
80°
79°
78°

Figure 41

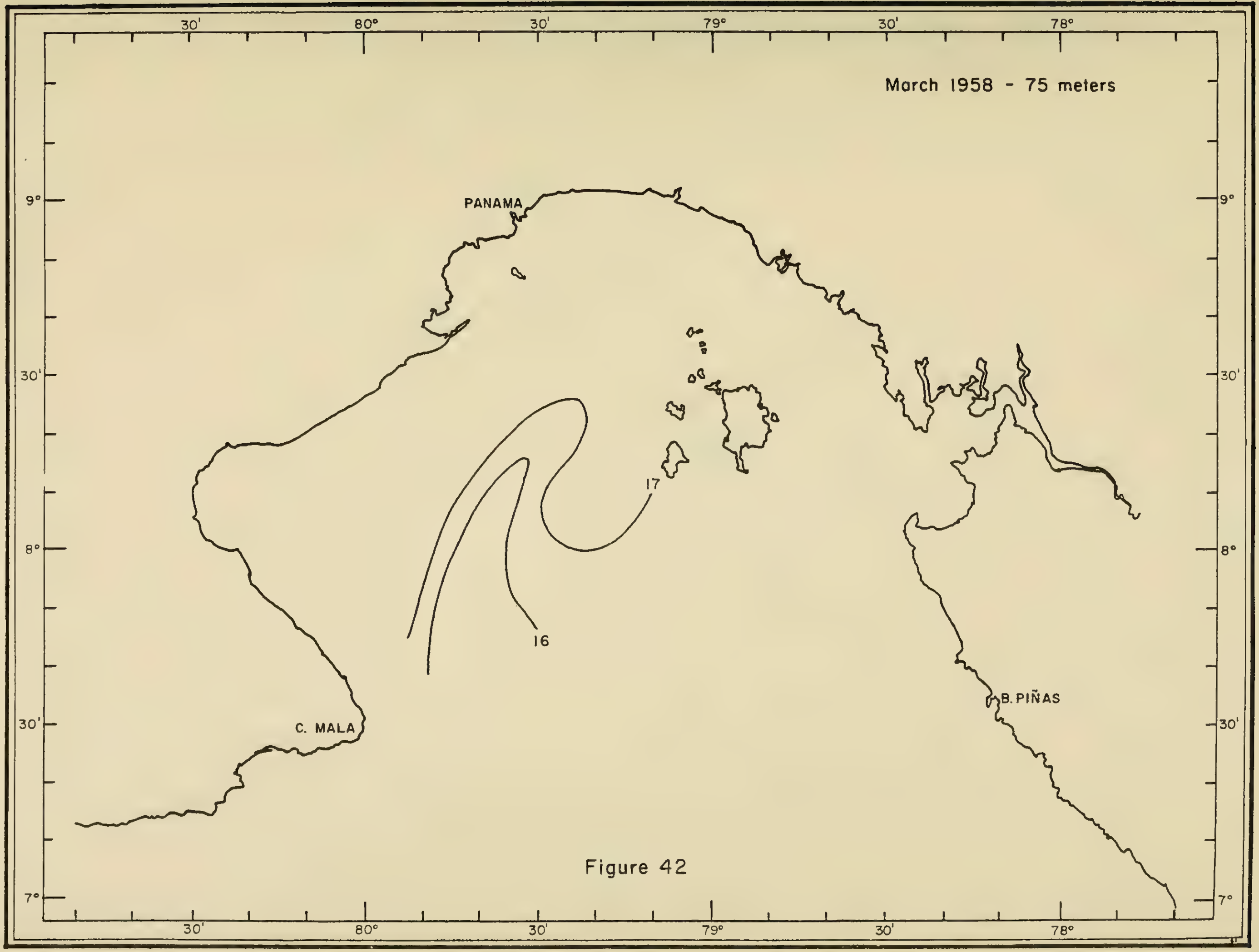

March 1958 - 75 meters
PANAMA
C. MALA
B. PIÑAS
17
16
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 42

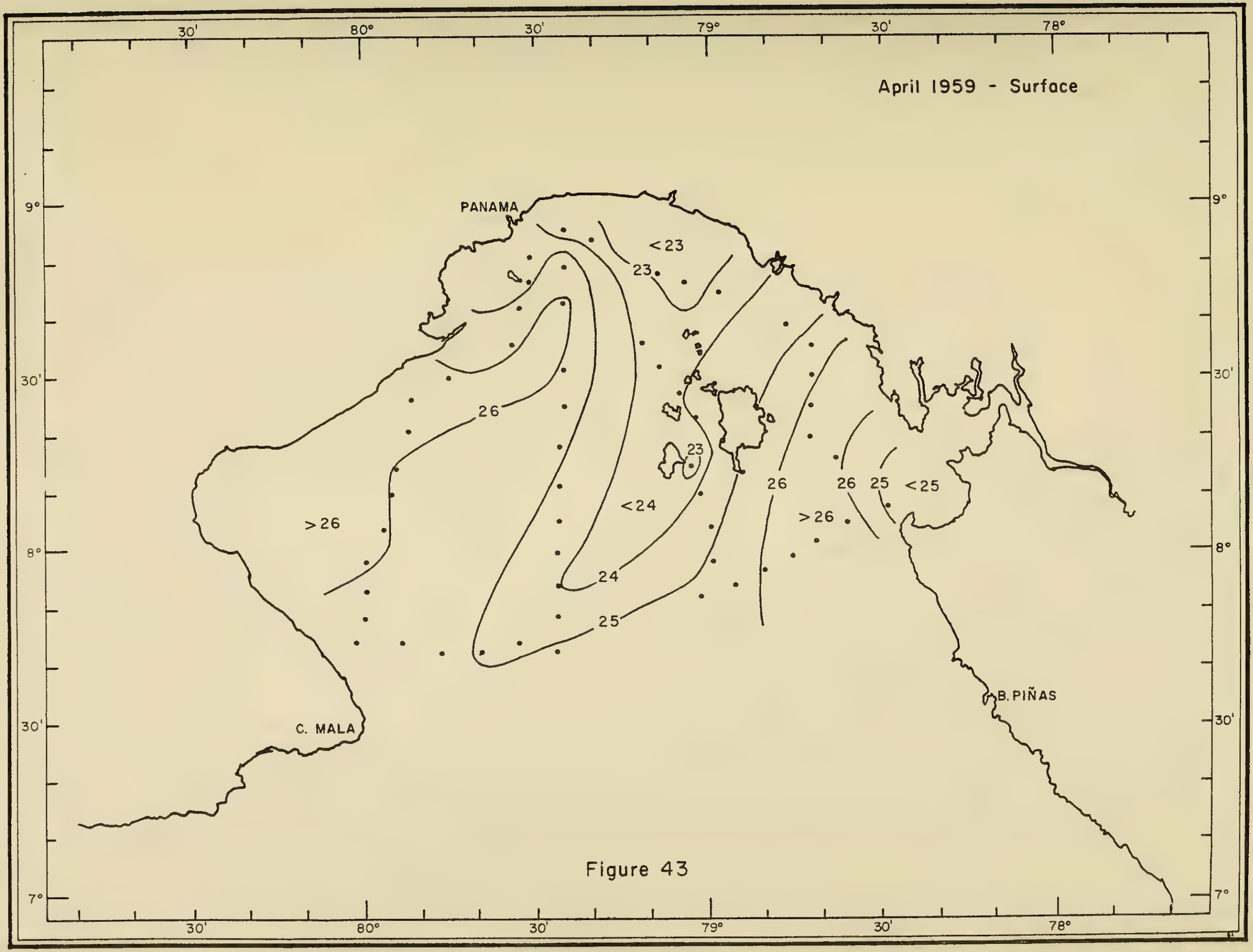

April 1959 - Surface
PANAMA
C. MALA
B. PIÑAS
<23
23
<24
24
25
<25
26
>26
9°
8°
7°
30'
80°
79°
78°

Figure 43

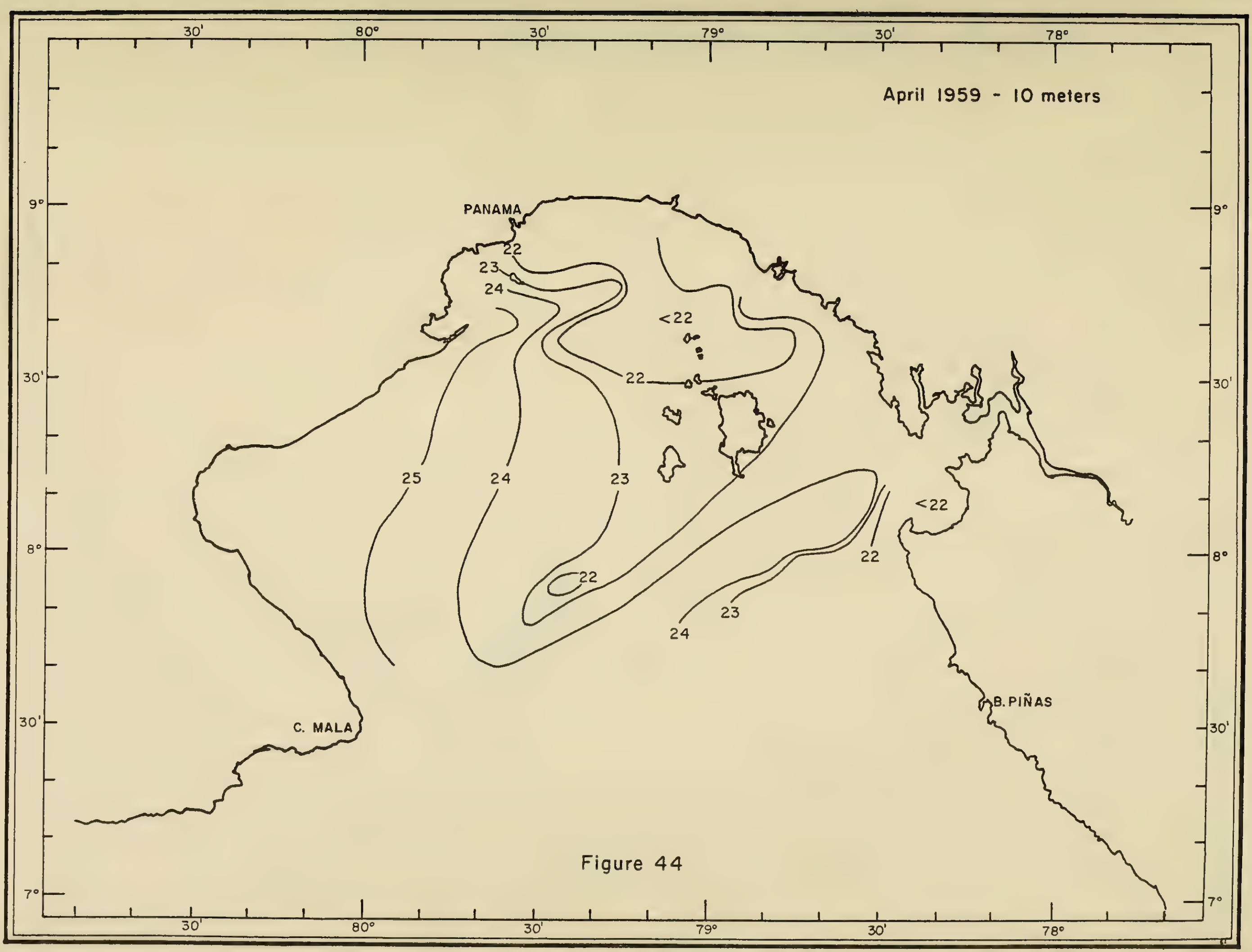

April 1959 - 10 meters
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
PANAMA
22
23
24
25
24
23
<22
22
22
<22
22
23
24
B. PIÑAS
C. MALA

Figure 44

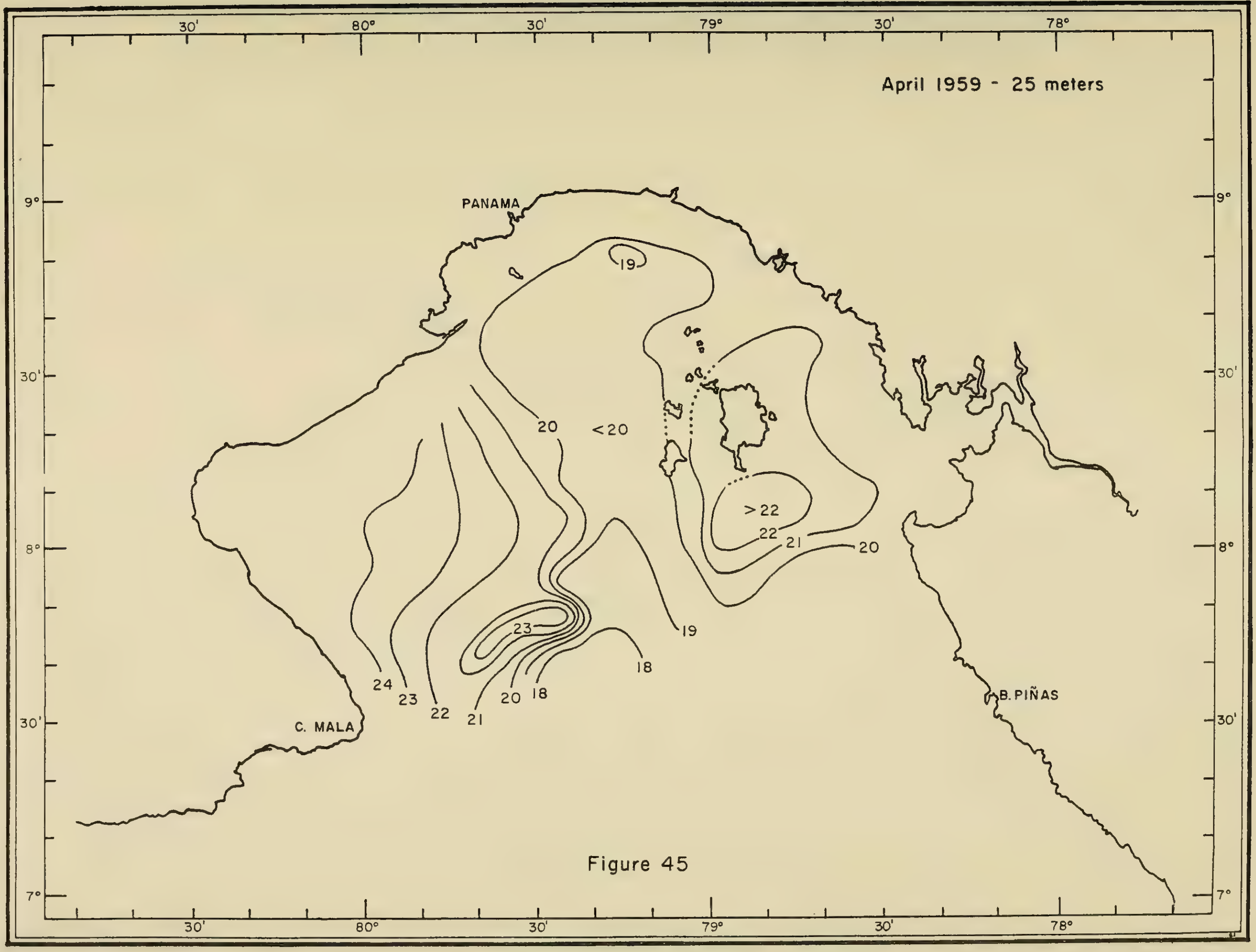

April 1959 - 25 meters
PANAMA
C. MALA
B. PIÑAS
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
19
<20
20
>22
22
21
20
19
18
23
24
23
22
21
20
18

Figure 45

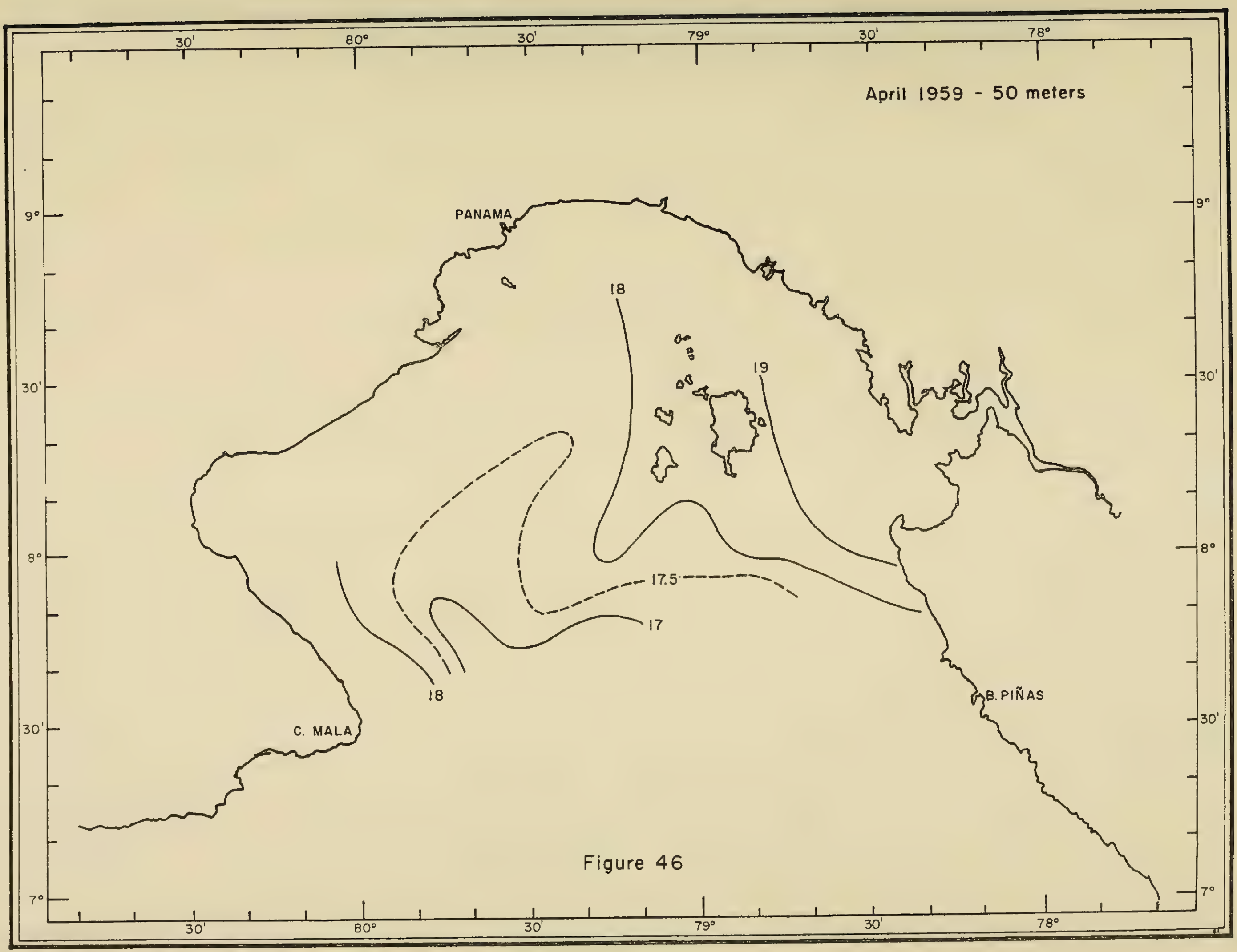
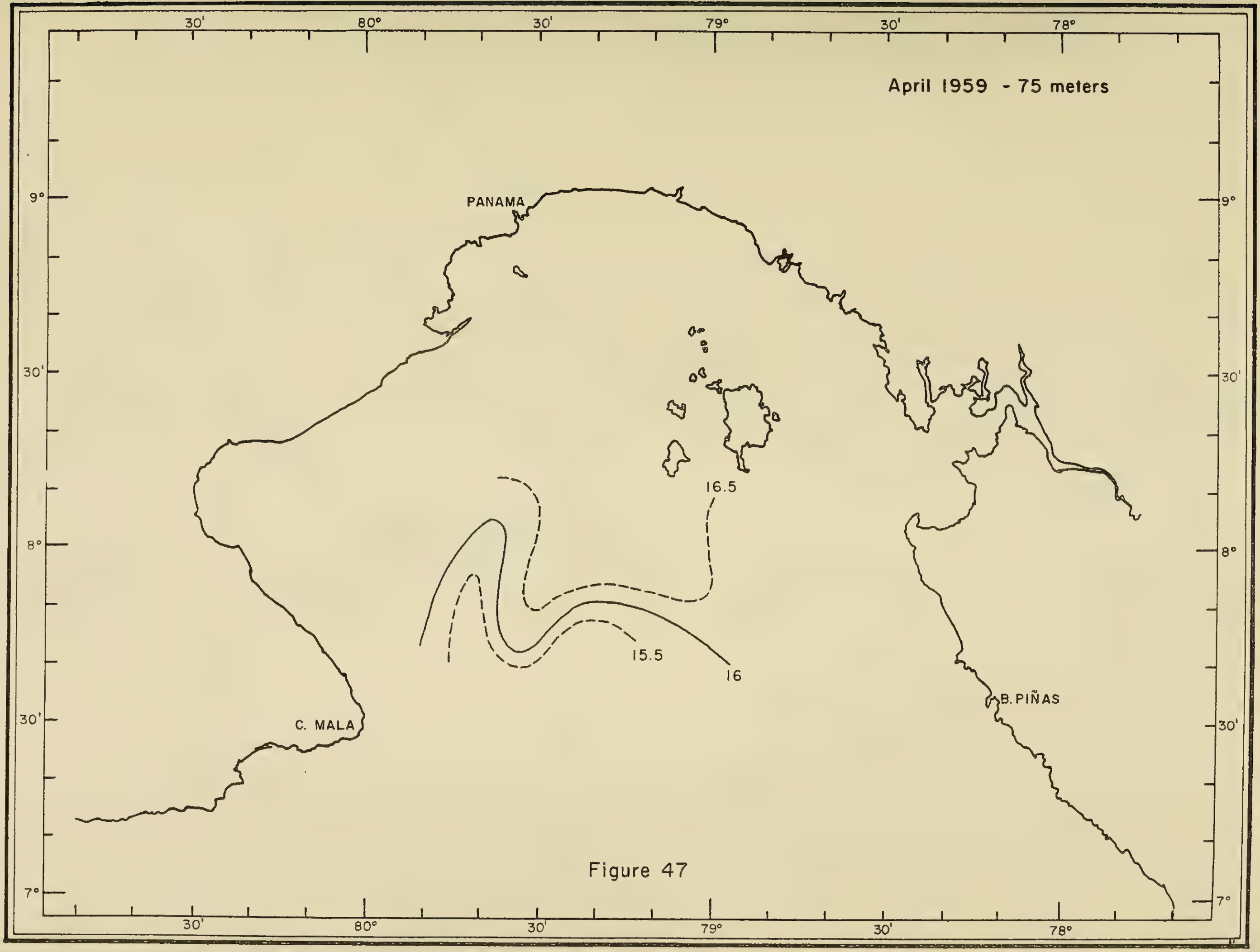
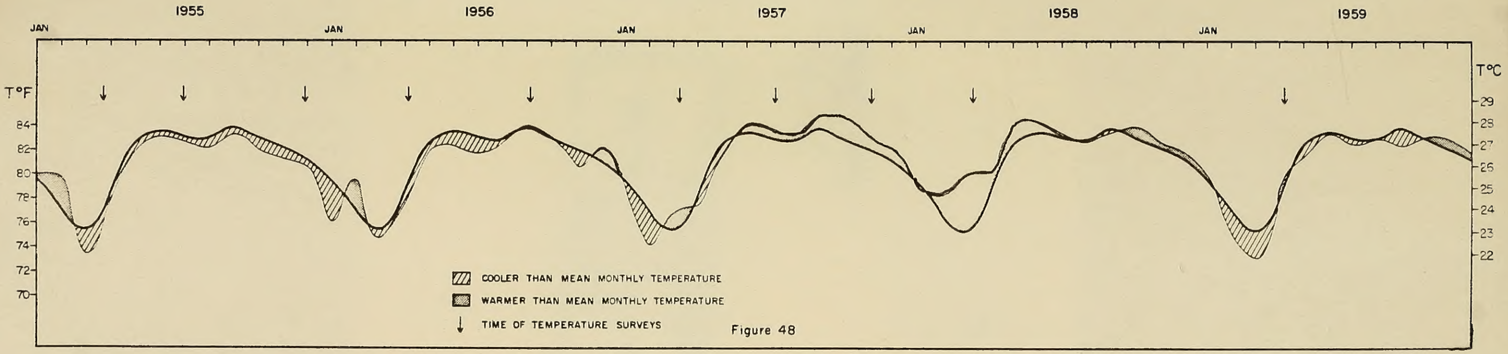

April 1959 - 50 meters
PANAMA
C. MALA
B. PIÑAS
19
18
17.5
17
18
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°

Figure 46



April 1959 - 75 meters
30'
80°
30'
79°
30'
78°
9°
30'
8°
30'
7°
PANAMA
C. MALA
B. PIÑAS
16.5
16
15.5

Figure 47



1955
1956
1957
1958
1959
JAN
JAN
JAN
JAN
JAN
T°F
84
82
80
78
76
74
72
70
T°C
29
28
27
26
25
24
23
22
COOLER THAN MEAN MONTHLY TEMPERATURE
WARMER THAN MEAN MONTHLY TEMPERATURE
TIME OF TEMPERATURE SURVEYS

Figure 48

Sund, Paul
1955–1959.
SHF

OUT

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726-AA

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